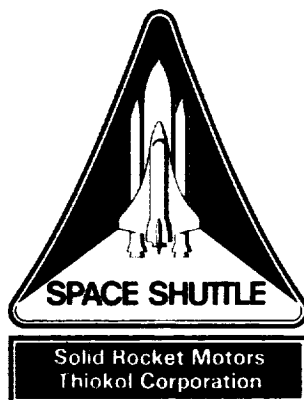


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Transportation Monitoring Unit Qualification Final Test Report

8 March 1990

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Transportation Monitoring Unit Qualification
Final Test Report

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ABSTRACT

Transportation monitoring unit (TMU) qualification testing was performed between 3 March and 14 December 1989. The purpose of the testing was to qualify the TMUs to monitor and store temperature and acceleration data on redesigned solid rocket motor segments and exit cones while they are being shipped from Utah's Thiokol Corporation, Space Operations, to Kennedy Space Center.

TMUs were subjected to transportation tests that concerned the structural integrity of the TMUs only, and did not involve TMU measuring capability. This testing was terminated prior to completion due to mounting plate failures, high- and low-temperature shutdown failures, and data collection errors. Corrective actions taken by the vendor to eliminate high-temperature shutdowns were ineffective.

An evaluation was performed on the TMUs to determine the TMU vibration and temperature measuring accuracy at a variety of temperatures. This test demonstrated that TMU vibration measurements are not within specified tolerances, that TMU measured shock levels are high, and that TMUs are temperature sensitive because of decreased accuracy at high and low temperatures.

It has been determined that modifications to the current TMU system, such that it could be qualified for use, would require a complete redesign and remanufacture. Because the cost of redesigning and remanufacturing the present TMU system exceeds the cost of procuring a new system that could be qualified without modification, it is recommended that an alternate transportation monitoring system be qualified.

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INTRODUCTION

This report documents the procedures, performance, and results obtained from the redesigned solid rocket motor (RSRM) transportation monitoring unit (TMU) Qualification test. The final series of testing was performed between 8 Nov and 14 Dec 1989 at Unisys Laboratories, Salt Lake City, Utah. Initial qualification testing was performed at the Wyle Test Facility, Norco, California, between 3 Mar and 5 Apr 1989. The purpose of the testing was to qualify the TMUs to monitor and store temperature and acceleration data on RSRM segments and exit cones while they are being shipped from Utah's Thiokol Corporation, Space Operations, to Kennedy Space Center (KSC). Testing was performed in accordance with CTP-0097, Transportation Monitor Unit Qualification Test Plan.

RSRM segments and exit cones are shipped to KSC on railcars. Each segment and exit cone-loaded railcar is instrumented to monitor acceleration and temperature during shipping. TMUs are mounted on each railcar to continuously store the temperature and acceleration data into temporary memory banks. This qualification testing was performed to demonstrate that TMUs can perform their required data gathering functions when subjected to temperatures and vibrations representative of the railcar environment.

1.1 TEST ARTICLE DESCRIPTION

The test article consisted of two TMUs, each assembled under 8U76218. TMU exterior configuration is shown in Figure 1. Specific information about the individual TMUs used at both the Wyle and Unisys test facilities is listed in Section 6, Results and Discussion. The TMUs were provided by vendor QSI Corporation, which refers to the TMUs as "QDLM-2" units.

TMU accelerometers are set for measurements in the longitudinal, vertical, and tangential (lateral) axes. Each axis has a programmed triggering operation which is set to function at 1.0-g longitudinal, 1.0-g vertical, and 0.5-g tangential threshold levels. Each accelerometer channel level is set to be recorded onto the main memory every time a preset acceleration level is exceeded. The main memory is also set to continuously store channel readings so that data are available for

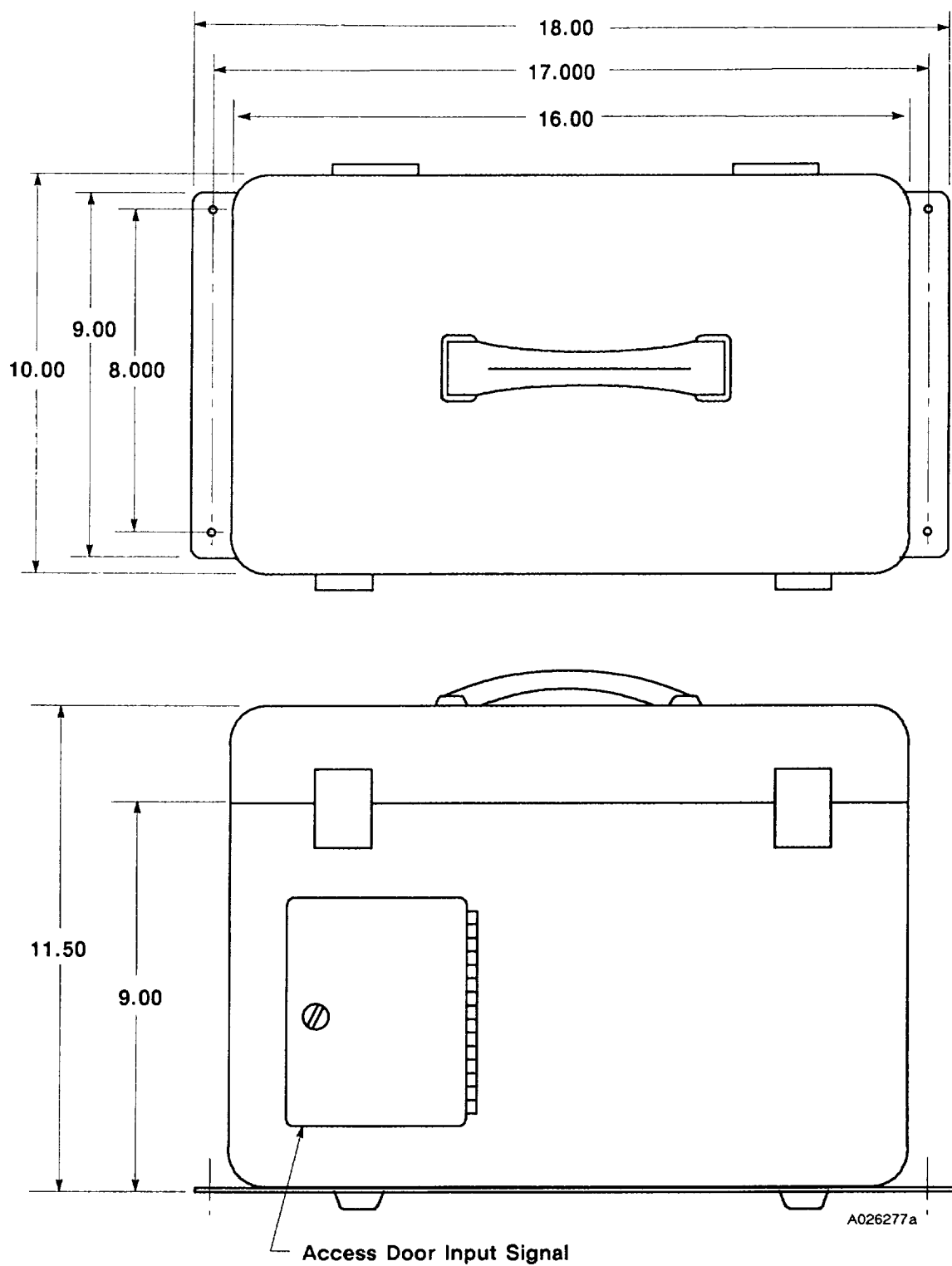


Figure 1. TMU Dimensions

recording 1 sec before and 10 sec after a triggered event. If acceleration levels are not exceeded, TMUs are set to automatically record each accelerometer level every 6 hr. Temperature levels are set to be recorded every 0.5 hr. TMUs are designed to store approximately 280 11-sec events. TMU and associated instrumentation placement on railcars is shown in Figures 2 and 3.

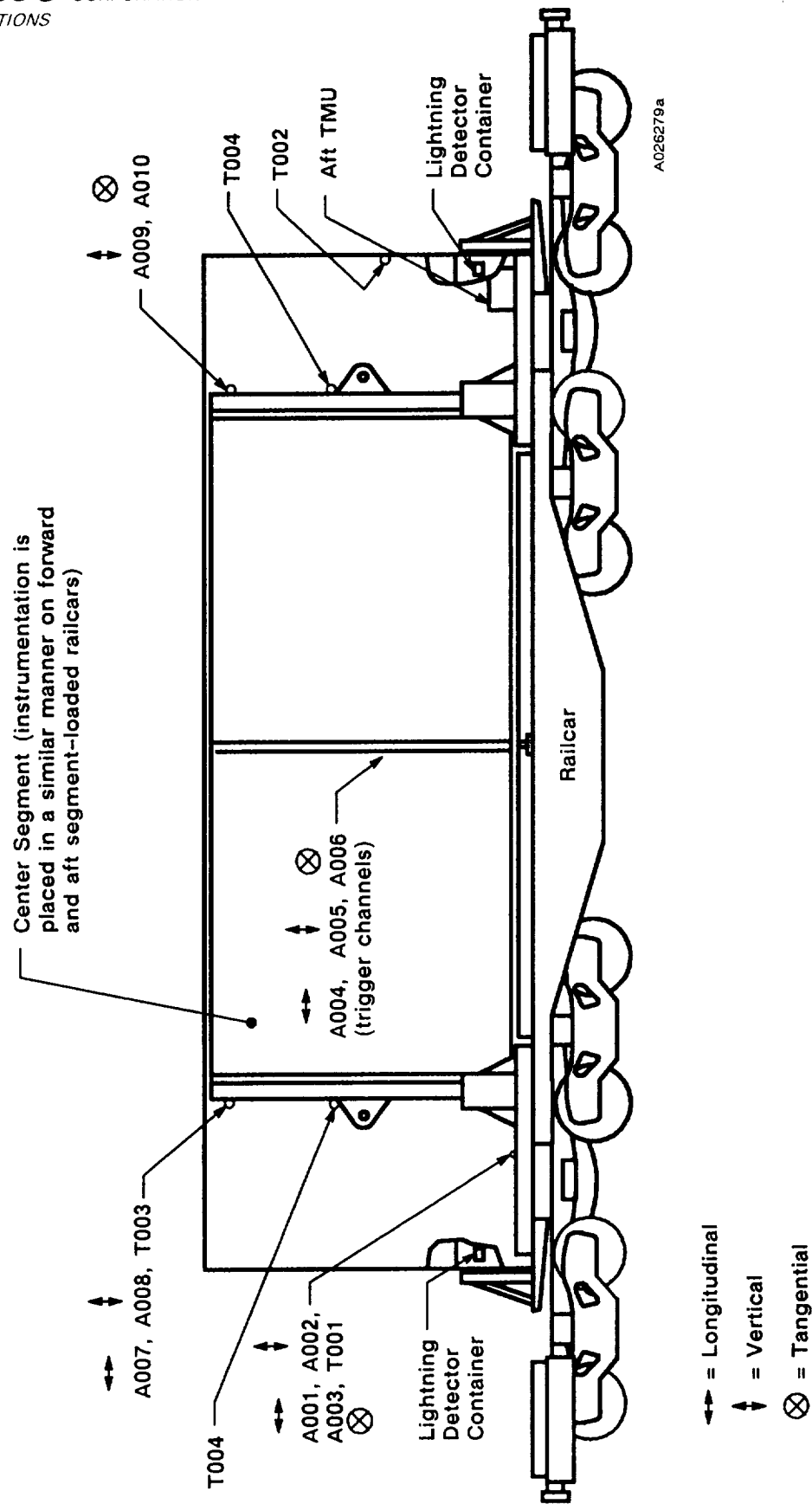


Figure 2. Instrumentation Locations on Segment-Loaded Railcar

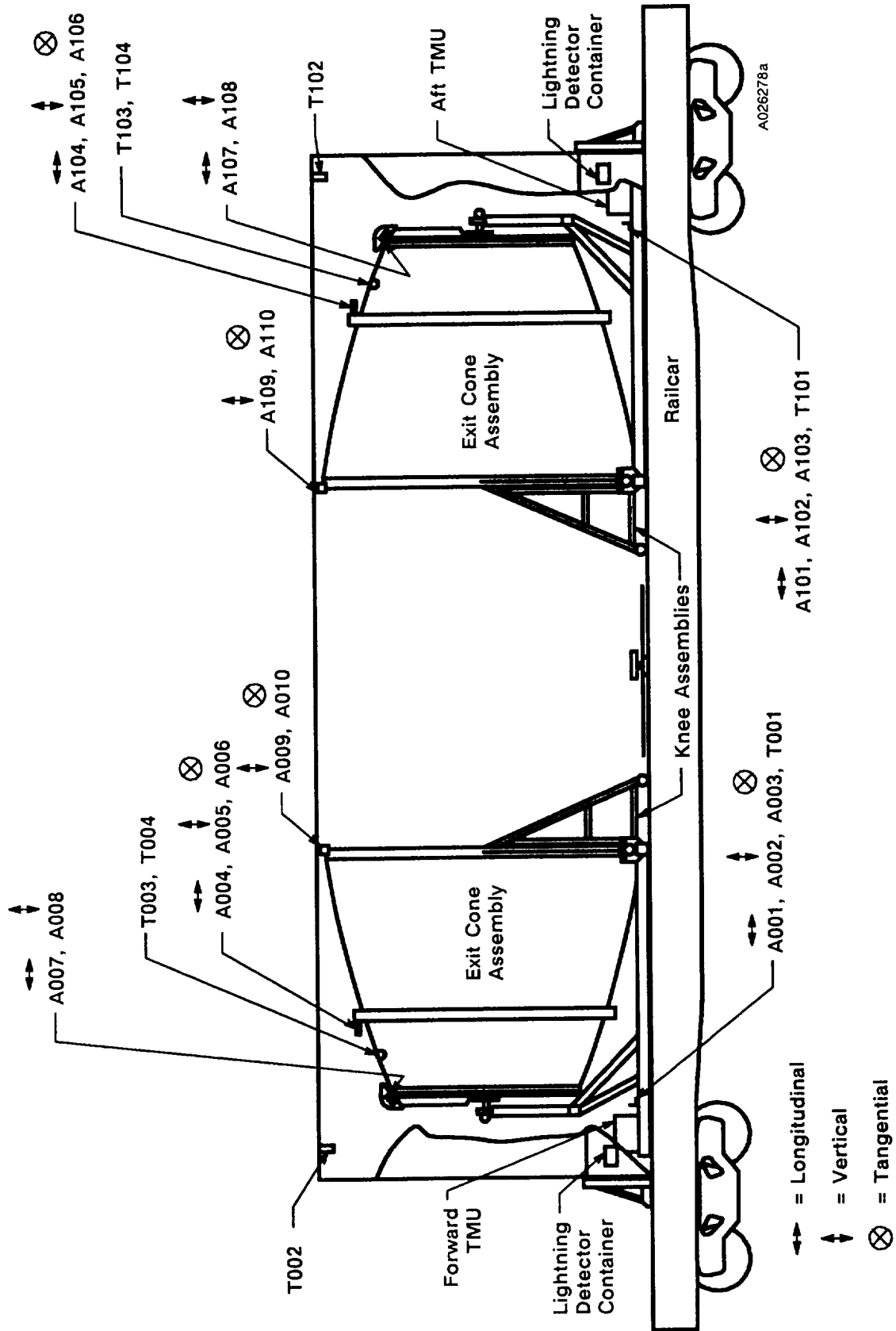


Figure 3. Instrumentation Locations on Exit Cone-Loaded Railcar

2

OBJECTIVES

The objectives of test plan CTP-0097 Rev D were derived to satisfy the requirements of the contract end item (CEI) Specification CPW1-3600 Para 3.2.8.b, and the railcar instrumentation identification item Specification CDW2-3454 as listed below.

The qualification objectives of the test were:

- A. Verify the general performance in accordance with CDW2-3454 Para 3.2.1.1.
- B. Verify the functional performance in accordance with CDW2-3454 Para 3.2.1.2.

The specific objectives of the test were:

- C. Certify that the unit scanner will record accelerations 1 sec before and 10 sec after each trigger.
- D. Certify that the TMU will record the 3-min timed event to assure clock accuracy.
- E. Certify that the TMU will record the temperature and internal parameters every 0.5 hr, starting at 1 min.
- F. Certify that the TMU will record a timed event every 6 hr starting with the first timed event at 3 min.
- G. Certify that the three accelerometer channels will trigger all other channels.
- H. Certify that the triggering systems operate at 1.0-g longitudinal, 1.0-g vertical, and 0.5-g tangential threshold levels.
- I. Certify acceleration and temperature accuracy throughout the operating temperature range.
- J. Certify the unit scanner recording capability through various vibration inputs.
- K. Certify that a nonoperational triggering channel will not affect the remaining channels and result in only one recorded event.
- L. Certify that the self-contained power source can successfully operate for a minimum of 17 days.

EXECUTIVE SUMMARY

3.1 SUMMARY

TMUs were subjected to transportation tests that concerned the structural integrity of the TMU only, and did not involve the measuring capability of the units. This testing was terminated prior to completion due to mounting plate failures, high- and low-temperature shutdown failures, and data collection errors.

An additional test for evaluation only was performed on the TMUs to determine the TMU vibration and temperature measuring accuracy at a variety of temperatures. This test demonstrated that TMU vibration measurements are not within specified tolerances, and that TMUs are temperature sensitive because of decreased accuracy at high and low temperatures.

The functional qualification tests were not performed, and none of the objectives of CTP-0097 were adequately addressed during the test. Results showed that TMUs do not perform to the requirements of the following documents: STW3-3662, CDW2-3454, TWR-17049 Rev A, nor the qualification testing of CTP-0097. A complete discussion of the test results is presented in Section 6.

3.2 CONCLUSIONS

Corrective actions taken by the vendor to eliminate high-temperature shutdowns were ineffective. The corrective actions are outlined in Appendices C and D.

The additional engineering evaluation demonstrated that TMU vibration measurements are not within specified tolerances, and that TMUs are temperature sensitive because of decreased accuracy at high and low temperatures. Because the TMU measured shock levels were higher than the input levels, it is likely that all the TMU measured shock levels are higher than what occurs at the accelerometers.

It has been determined that modifications to the current TMU system, such that it could be qualified for use, would require a complete redesign and remanufacture.

3.3 RECOMMENDATIONS

Because the TMUs failed to survive their simulated use environment, and because the cost of redesigning and remanufacturing the present TMU system exceeds the cost of procuring a new system that could be qualified without modification, it is recommended that an alternate transportation monitoring system be qualified to monitor RSRM segment and exit cone shipments.

4

INSTRUMENTATION

Instrumentation used and recording system trigger levels were as listed in CTP-0097. All reference, control, and response instruments were zeroed and calibrated in accordance with MIL-STD-45662.

5

PHOTOGRAPHY

Photographs of the test setup at Wyle Laboratories and the broken TMU mounting plate are included in Appendix A, Pages A-71 and A-72.

Photographs of the test setup at Unisys were also taken, and are shown in Figures 4 through 6.

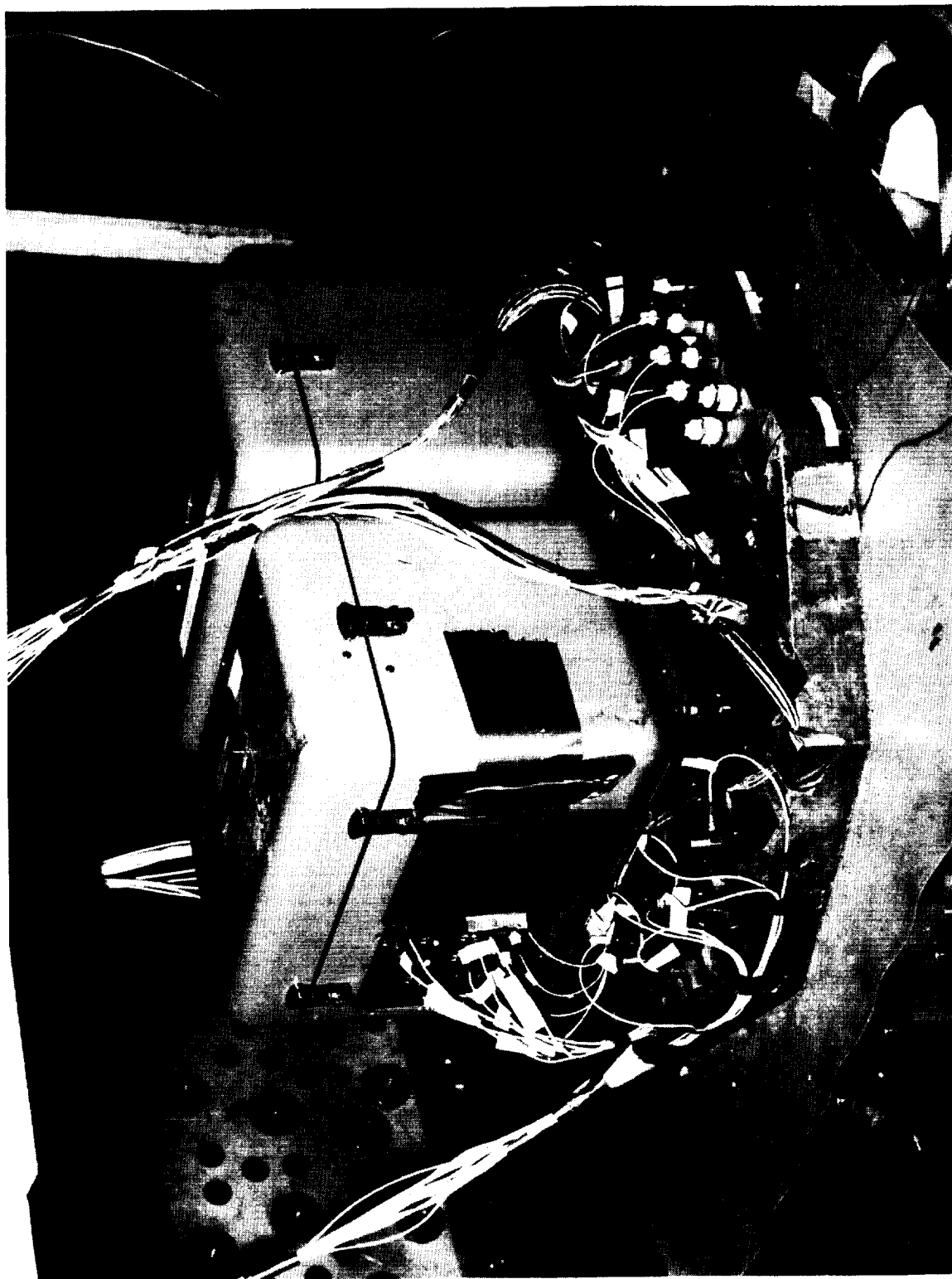


Figure 4. TMU Test at Unisys — Test Setup

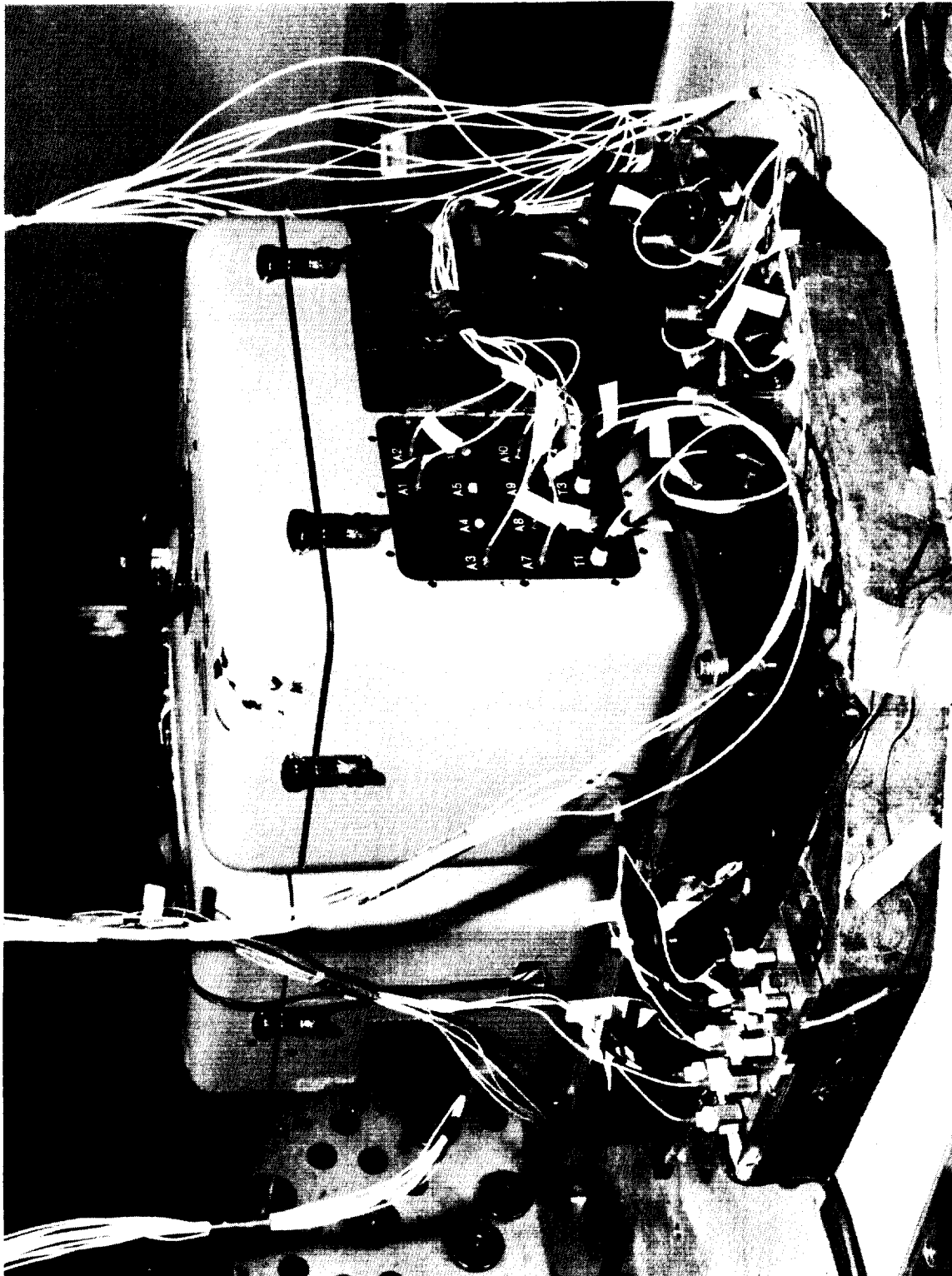


Figure 5. TMU Test at Unisys — Test Setup

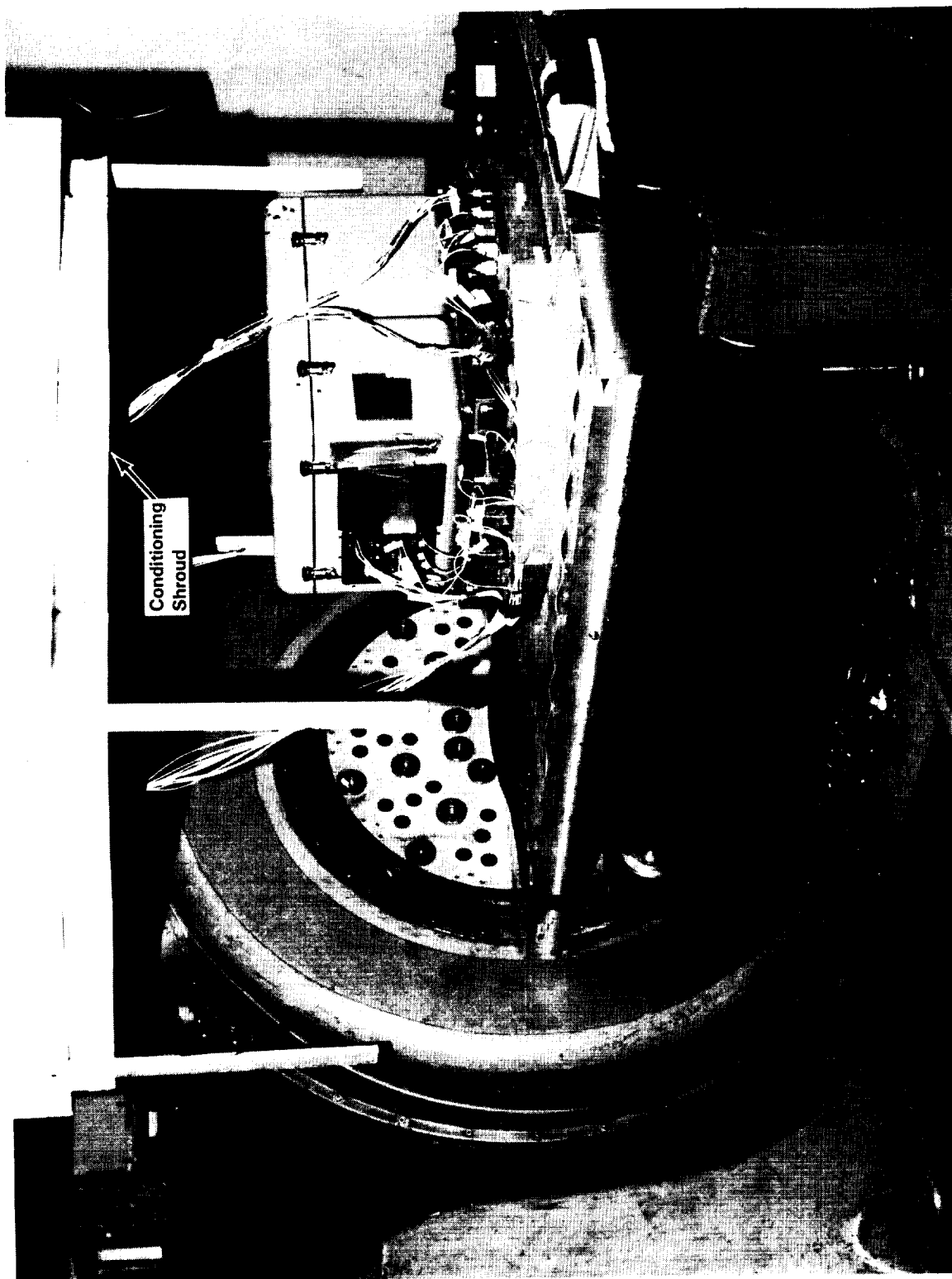


Figure 6. TMU Test at Unisys — Test Setup

RESULTS AND DISCUSSION

6.1 TESTING AT WYLE LABORATORIES

This portion of testing was performed between 3 Mar and 5 Apr 1989 at the Wyle Test Facility, Norco, California. A representative from Systems Loads and Environments witnessed the majority of testing.

Wyle prepared a test report which includes plots of the test results. This report is included as Appendix A. Section 6.1 summarizes the Wyle test report and provides additional information and conclusions.

6.1.1 Test Article Description

The test article consisted of two TMUs, prototype units No. 1 (S/N 0006) and No. 2 (S/N 0013). Both TMUs were subjected to the same testing. The TMU shock mounts were fastened to "U" channels and then secured to an electrodynamic exciter. Thermocouples and accelerometers were then mounted on the TMU and shaker table as shown on Page 5 of the Wyle test report. Test configuration was as specified in CTP-0097.

For temperature conditioning, a 3-foot-square insulated plywood box was placed around the TMU. Hot air or CO₂ was forced into the box for heating and cooling, respectively.

6.1.2 Transportation Testing

6.1.2.1 Introduction. Testing began by addressing the transportation portion of CTP-0097. This was a structural test of the TMU components and housings, designed to verify extended operation of the TMU in the intended environment of railcar operation.

This testing consisted of subjecting the TMUs to sine sweep vibrations to determine the TMU resonant frequencies, subjecting the TMUs to sinusoidal dwell vibrations at the resonant frequencies, and subjecting the TMUs to shock spectra testing.

This testing began with sinusoidal sweep vibrations applied to the TMUs to determine the resonant frequencies for each unit. Sine sweep vibrations were applied in accordance with SE-019-049-2H, "Solid Rocket Booster Vibration, Acoustic

and Shock Design and Test Criteria," and the test criteria for determining resonant frequencies is listed in Table 1. Resonant frequencies for each TMU were determined by greater than 2-to-1 amplification ratios between any response accelerometer (mounted on the outside surface of the top of the TMU) and the control accelerometer (mounted on top of the shaker table). Resonant frequencies were to be found in the longitudinal, tangential, and vertical axes at -20°, 70°, and 163°F. Response accelerations that were measured in the same axis as the control input axis were used to determine resonant frequencies.

**Table 1. TMU Transportation Test Criteria--Control Inputs
for Determining Resonant Frequencies (sine sweep
through the below range at 5-2,000-5 Hz at
1 octave/minute)**

- 5 to 130 Hz at 1.2-g peak
- 130 to 185 Hz at 0.0014-in. double amplitude
- 185 to 2,000 Hz at 2.5-g peak

Once resonant frequencies were determined, TMUs were then subjected to sinusoidal dwell testing for 15 min at the approximate sine sweep amplitudes for each resonant frequency. No more than three sine dwells were applied in a single axis for a given temperature.

The TMUs were also to be subjected to five shocks in each direction in the longitudinal, tangential, and vertical axes at -20°, 70°, and 163°F. The shock spectra levels are defined in Table 2.

Table 2. TMU Transportation Shock Test Criteria

- 20 to 160 Hz at +6 decibel/octave
- 160 to 340 Hz at 10-g peak
- 340 to 400 Hz at -6 decibel/octave

The data acquisition system and TMU zero reference (located on TMU display panel) were to be verified prior to testing, after completion of each test. Memory modules were to be removed and replaced each time that TMUs were turned off.

TMU accelerometer trigger channels were not connected for measurements. Temperature measurements were taken by the TMU internal and external instrumentation throughout the tests.

6.1.2.2 Transportation Testing With Original Shock Mounts and Mounting Plate. Initial testing was performed with the original design TMU shock mounts which consisted of two bolts enclosed within a rubber grommet. The original design 0.125-in. thick aluminum mounting plate was used.

TMU Time Check Sequence Test. Prior to testing, a time check sequence was run on each TMU. Both units were run continuously for 6 hr. Each TMU recorded at the 0.5- and 6-hr intervals.

-20°F Testing. TMU No. 1 was conditioned to -20°F and run through a longitudinal sine sweep. Once sine sweep testing began, it was evident that the shock mounts significantly increased the vibration amplitudes that were input to the TMUs from the shaker table. Regardless of the high amplitudes, it was decided to proceed with testing. Two resonant frequencies were found at approximately 22 and 31 Hz (Page 12 of the Wyle test report). The unit was then subjected to sine dwell vibration testing at these frequencies (at -20°F) for 15 min with no structural damage occurring.

(Frequency versus acceleration plots, included in the Appendix A, consist of control and response accelerations. Plots for resonant sine dwell tests were not taken, as these were pass/fail tests.)

TMU No. 1 was then subjected to shock spectra testing in the longitudinal axis at -20°F. Results of the shock tests begin on Page 43 of the Wyle test report. The TMU continued to run while subjected to the shock tests.

TMU No. 2 was then conditioned to -20°F and run through a longitudinal sine sweep. Two resonance frequencies were found at approximately 28 and 39 Hz (Page 12 of the Wyle test report). The unit was then subjected to sine dwell vibration testing at these frequencies (at -20°F) for 15 min with no structural damage occurring.

TMU No. 2 was then subjected to shock spectra testing in the longitudinal axis at -20°F. Results of the shock tests begin on Page 43 of the Wyle test report. The TMU continued to run while subjected to the shock tests.

During these cold transportation tests, both the Wyle control thermocouple and the TMU internal temperature sensor indicated approximately -20°F, while the four TMU external temperature sensors indicated approximately 0°F. Since the vibration table was significantly larger than the conditioning chamber, it was not possible to lower the table surface temperature below 0°F. The table surface temperature probably influenced the attached TMU external temperature sensor readings. Also, probe measurements were probably inaccurate because they were uninsulated and became coated with ice from the carbon dioxide. Prior to additional testing, this temperature difference was eliminated by insulating the temperature probes from the vibration table with a 2-in. thick layer of fiberglass insulation between the probes and the shaker table surface.

70°F Testing. TMU No. 1 was subjected to shock spectra testing in the longitudinal axis at 70°F. Results of the shock tests begin on Page 43 of the Wyle test report. The TMU continued to run while subjected to the shock tests.

Sine sweep testing of TMU No. 2 in the longitudinal axis at 70°F resulted in a resonant frequency at approximately 19 Hz (Page 20 of the Wyle test report). The unit was then sine dwell tested at approximately 19 Hz for 15 min and no structural damage occurred. Post-test inspection revealed that two mounting screws had loosened during the sine dwell test. The loose mounting screws were retightened.

TMU No. 2 was then subjected to shock spectra testing in the longitudinal axis at 70°F. Results of the shock tests begin on Page 43 of the Wyle test report. The TMU continued to run while subjected to the shock tests.

Sine sweep testing of TMU No. 1 in the longitudinal axis at 70°F resulted in a resonant frequencies at approximately 16, 21, and 32 Hz (Page 24 of the Wyle test report). The peak acceleration loads for the 16-Hz resonance frequency were relatively high at 50 g. When the unit was subjected to sine dwell vibration at approximately 14.5 Hz and 1.2 g input, the mounting plate fractured prior to completion of the 15 min sine dwell. A photo of the broken mounting plate is shown on Page 72 of the Wyle test report.

Testing was then terminated and effort was directed toward improving the mounting plate and shock mounts to withstand the vibration test levels.

6.1.2.3 Transportation Testing with Redesigned Shock Mounts and Mounting Plate.
As a result of the mounting plate failure during the initial testing at the Wyle test

facility, the shock mounts and mounting plate were redesigned and installed, and testing was started over. The improved mounting plate was made from 0.125-in. thick stainless steel, reinforced at each end with additional 0.125-in. thick stainless steel. The improved shock mounts consisted of a single bolt with an external rubber grommet, as compared to the original dual bolt design.

For the cold temperature testing, plastic was loosely taped around the temperature probes to prevent surface condensation and frost. Also, a 2-in. layer of insulation was wrapped around the accelerator connections with Teflon[®] tape, and unused accelerometer connections were wrapped with Teflon[®] tape to avoid shorts due to condensation.

TMU Time Check Sequence Test. Prior to testing, a time check sequence was run on each TMU. Both units were run continuously for 18 hr. Each TMU recorded at the 0.5-hr and 6-hr intervals.

Tangential Axis Testing. Because tangential vibrations subjected the TMUs to the largest amplitude response (the TMUs were most likely to fail due to loads in this direction), it was decided to test in the tangential direction first.

TMU No. 1 was conditioned to -20°F and run through a tangential sine sweep. One resonant point was found at approximately 17 Hz (Page 28 of the Wyle test report). The unit was then subjected to sine dwell vibration testing at this frequency for 15 min at -20°F with no structural damage occurring.

Tangential sine sweep testing of TMU No. 1 at 70°F resulted in resonant points at approximately 16 and 55 Hz (Page 32 of the Wyle test report). The unit then passed sine dwell testing at these levels with no structural damage occurring.

Sine sweep testing of TMU No. 2 at 70°F resulted in one resonance point at approximately 28 Hz (Page 40 of the Wyle test report). The unit then passed sine dwell testing at these levels with no structural damage occurring.

TMU No. 1 was then conditioned overnight to 163°F. The next morning, the unit was subjected to sine sweep testing in the tangential direction, with resonance points found at approximately 14.5 and 43 Hz (Page 37 of the Wyle test report). The TMU was then subjected to sine dwell testing at these resonance points, and no structural damage to the TMU occurred. Results showed that resonant frequencies decreased as temperatures increased. This is because the shock mounts became less stiff at higher temperatures, causing larger TMU response amplitudes and more time between peaks.

When the TMU was removed from the conditioning chamber after the sine dwell tests, it was not running. The TMU had stopped recording data when the heat conditioning began. Upon cooling to ambient temperature, the unit was restarted. Vibration testing per CTP-0097 was then halted to further investigate why unit No. 1 shut down.

High-Temperature Failure Testing. In an effort to determine the TMU shutdown temperature, both TMUs were placed in the conditioning chamber and then the chamber was heated to 120°F. Because the TMU lids were left open, the modules of each TMU may have been subjected to a more severe environment than the railcar environment. Both units continued to run for 5 to 10 min at the chamber temperature of 120°F. The temperature of the chamber was then increased to 150°F. After approximately 5 min, TMU No. 1 shutdown, while TMU No. 2 continued to run. Testing was then terminated to preclude further damage to the TMUs, since it was evident that the units could not withstand the specified upper temperature limit.

Further evaluation of the TMUs by QSI Corporation revealed that a bad component within the TMUs caused the high-temperature TMU failure. QSI Corporation changed the TMU components as explained in Section 6.2.1.

Truncated Data Failure. In addition to the high-temperature failure, approximately 1 percent of all TMU acceleration response data collected randomly during the Wyle test was incomplete. The incomplete data were the result of a truncation error. QSI Corporation determined that the truncation error was related to the TMU software. QSI made software modifications to fix the truncation errors, as explained in Section 6.2.1.

Summary. As a result of the termination of testing (due to the mounting plate, high-temperature shutdown, and data collection errors), the transportation testing was incomplete. The functional and electromagnetic interference (EMI) tests were not performed, and none of the objectives of CTP-0097 were adequately addressed during the Wyle test. Further testing was planned.

6.2 TESTING AT UNISYS

This portion of testing was performed between 8 and 28 Nov 1989 at Unisys Laboratories, Salt Lake City, Utah. A representative from Systems Loads and Environments witnessed the majority of testing.

Unisys prepared a test report which includes portions of the test procedures, test logbooks, and test result plots for the qualification portion of testing. This report is included as Appendix B. Section 6.2 summarizes the Unisys test report and provides additional information and conclusions.

Test Criteria Changes Since Wyle Testing. Prior to the Unisys testing, the following changes were made to test plan CTP-0097 and to the TMU product specification STW3-3662:

- Objective L was added to CTP-0097, which required the TMUs to be capable of continuously running, under their own power source, for 17 days.
- Because NASA did not expect the TMUs to be subjected to EMI during the shipping process, the EMI requirements of STW3-3662 were deleted.
- The test temperature limits were changed to meet the STW3-3662 requirements of -30° to 153°F. The minimum and maximum temperature requirements were adjusted to -40° ±10°F and 163° ±10°F.
- It was also determined that the dwell tests were significantly more harsh than the railcar environment, and therefore the option to replace each shock mount after each axis test was instated.

6.2.1 Test Article Description

The test article consisted of two TMUs: one TMU (S/N 5000007) was used for qualification, and the other TMU (S/N 5000017) was used for engineering evaluation to gather and reduce data during the test. The TMUs were assembled under the requirements of drawing 8U76218.

The TMU mounting plate was again changed. The new mounting plate was made from solid 0.250-in. thick steel.

The Unisys test facility provided the test fixture, reference/control accelerometer, reference temperature sensor, response accelerometers, and associated data acquisition systems. The TMUs were configured as shown in Figures 4 through 6.

QSI Corporation determined that the Wyle TMU test failures were related to TMU software errors (data truncation error) and a TMU internal component failure (high-temperature failure). QSI made improvements to the TMUs prior to the Unisys testing. The QSI improvements are outlined in the memo, QDLM-2 Failure

Analysis (Wyle Laboratories qualification testing), and the report, Failure Analysis of TMUs No. 0006 and No. 0013, included as Appendices C and D, respectively.

6.2.3 Transportation Testing

Refer to Section 6.1.2.1 for information about transportation testing.

TMU Time Check Sequence Test. Prior to testing, a time check sequence was run on each TMU. Both units were run continuously for 6 hr. Each TMU recorded at the 0.5-hr and 6-hr intervals.

-40°F Testing. Both TMUs were placed inside the conditioning chamber and were conditioned to approximately -40°F. Sine sweep vibrations were then applied in the longitudinal axis (plots of longitudinal vibration testing at -40°F are shown in Appendix B of the Unisys test report). Two resonant frequencies were found at approximately 46 and 95 Hz. The units were then subjected to sine dwell vibration testing at these frequencies (at -40°F) for 15 min with no structural damage occurring. The TMUs were then subjected to shock spectra testing in the longitudinal axis at -40°F. Both TMUs continued to run while subjected to the shock tests.

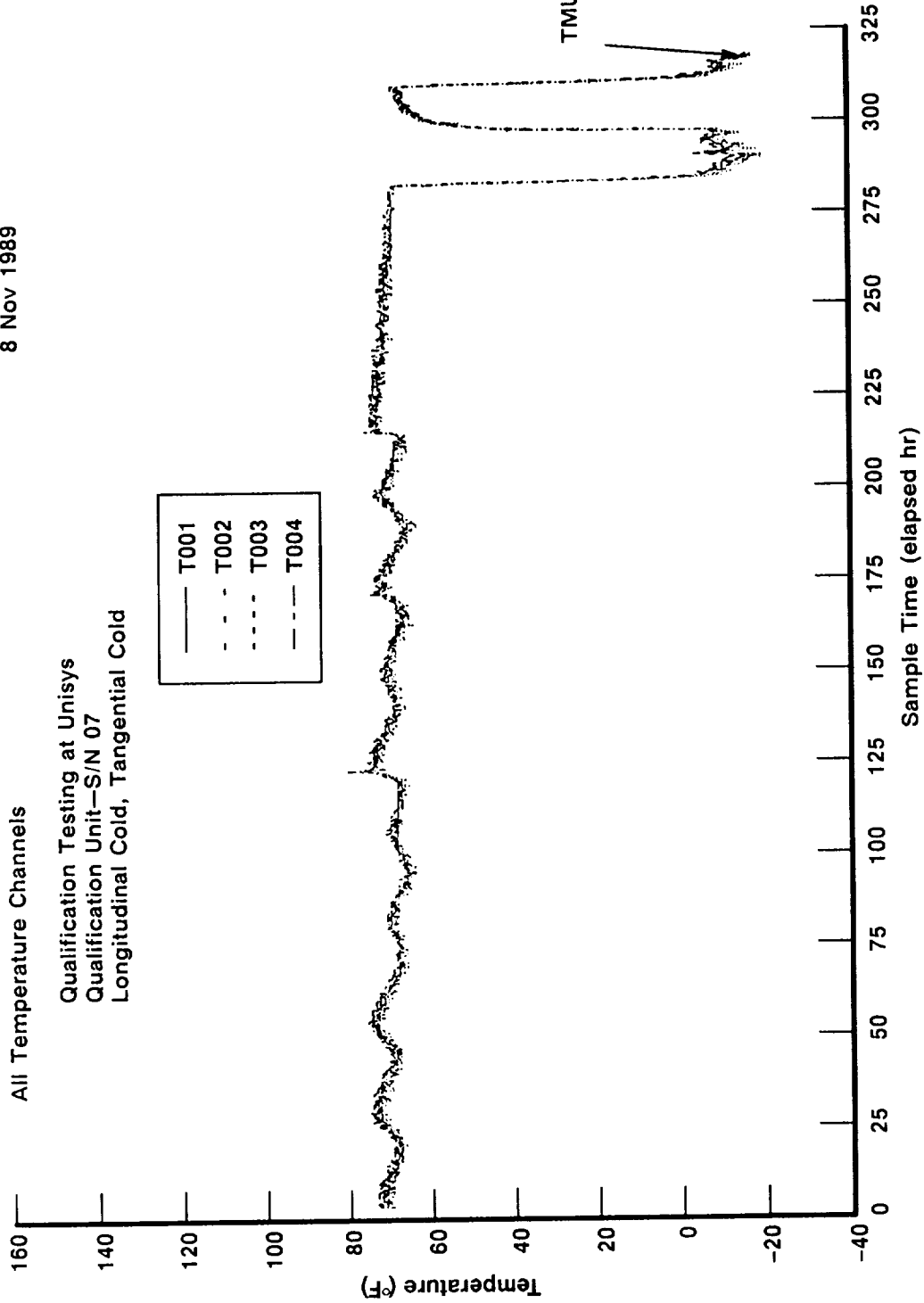
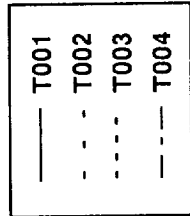
Orientation of the TMUs was then changed for vibration testing in the tangential axis (plots of tangential vibration testing at -40°F are shown in Appendix C of the Unisys test report). Both TMUs were conditioned to approximately -40°F and were subjected to sine sweep vibrations in the tangential axis. One resonant frequency was found at approximately 38 Hz. The units were subjected to sine dwell vibration testing at this frequency for 15 min with no structural damage occurring. The TMUs were then subjected to shock spectra testing in the tangential axis at -40°F.

Upon removal of the conditioning chamber after the shock testing, the TMUs were found to have shut down. The 17-day continuous-running requirement was not met because the TMUs had only run for 14 days. TMU measured results show that the battery voltage dropped below the required level and caused the TMUs to fail approximately 18 hr into the cold conditioning period. Figure 7 shows the cold temperature TMU failure on a time versus temperature plot. Thiokol concluded that the alkaline batteries within the TMU could not provide the TMUs with adequate voltage within a -40°F environment.

8 Nov 1989

All Temperature Channels

Qualification Testing at Unisys
Qualification Unit—S/N 07
Longitudinal Cold, Tangential Cold



Zero Time: 00 11:58:00
1 Sample/0.5 hr

Figure 7. TMU Temperature Response Versus Time—Cold Temperature Failure

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It was determined that the TMUs would be restarted and testing would be continued, provided that the TMUs were not subjected to cold environments for an extended amount of time. New batteries were installed, and the TMUs were started again, beginning a new 17-day test.

70°F Testing. Prior to the ambient temperature testing, each of the TMU shock mounts was replaced. Both TMUs were conditioned to approximately 70°F. Sine sweep vibrations were then applied in the tangential axis (plots of tangential vibration testing at 70°F are shown in Appendix D of the Unisys test report). Two resonant frequencies were found at approximately 26 and 86 Hz. The units were then subjected to sine dwell vibration testing at these frequencies (at 70°F) for 15 min with no structural damage occurring. The TMUs were then subjected to shock spectra testing in the tangential axis at 70°F. Both TMUs continued to run while subjected to the shock tests.

Orientation of the TMUs was then changed for vibration testing in the longitudinal axis (plots of longitudinal vibration testing at 70°F are shown in Appendix E of the Unisys test report). Both TMUs were conditioned to approximately 70°F and were subjected to sine sweep vibrations in the longitudinal axis. One resonant frequency was found at approximately 35 Hz. The units were subjected to sine dwell vibration testing at this frequency for 15 min with no structural damage occurring. The TMUs were then subjected to shock spectra testing in the longitudinal axis at 70°F. Both TMUs continued to run while subjected to the shock tests.

163°F Tests. The TMUs were then conditioned to approximately 163°F for 4 hr. Sine sweep vibrations were then applied in the longitudinal axis (plots of longitudinal vibration testing at 163°F are shown in Appendix F of the Unisys test report). Three resonant frequencies were found at approximately 33.4, 71, and 93 Hz. The units were then subjected to dwell vibration testing at these frequencies (at 163°F) for 15 min with no structural damage occurring. The TMUs were then subjected to shock spectra testing at 163°F.

After the vibration testing in the longitudinal axis, the conditioning shroud was removed, and the TMUs were not running. TMU data revealed that both TMUs shut down during the 4 hr of hot conditioning, prior to the actual vibration testing. Figure 8 shows the TMU high-temperature failure on a time versus temperature

22 Nov 1989

All Temperature Channels

Qualification Testing at Unisys
Qualification Unit—S/N 07, Second Attempt

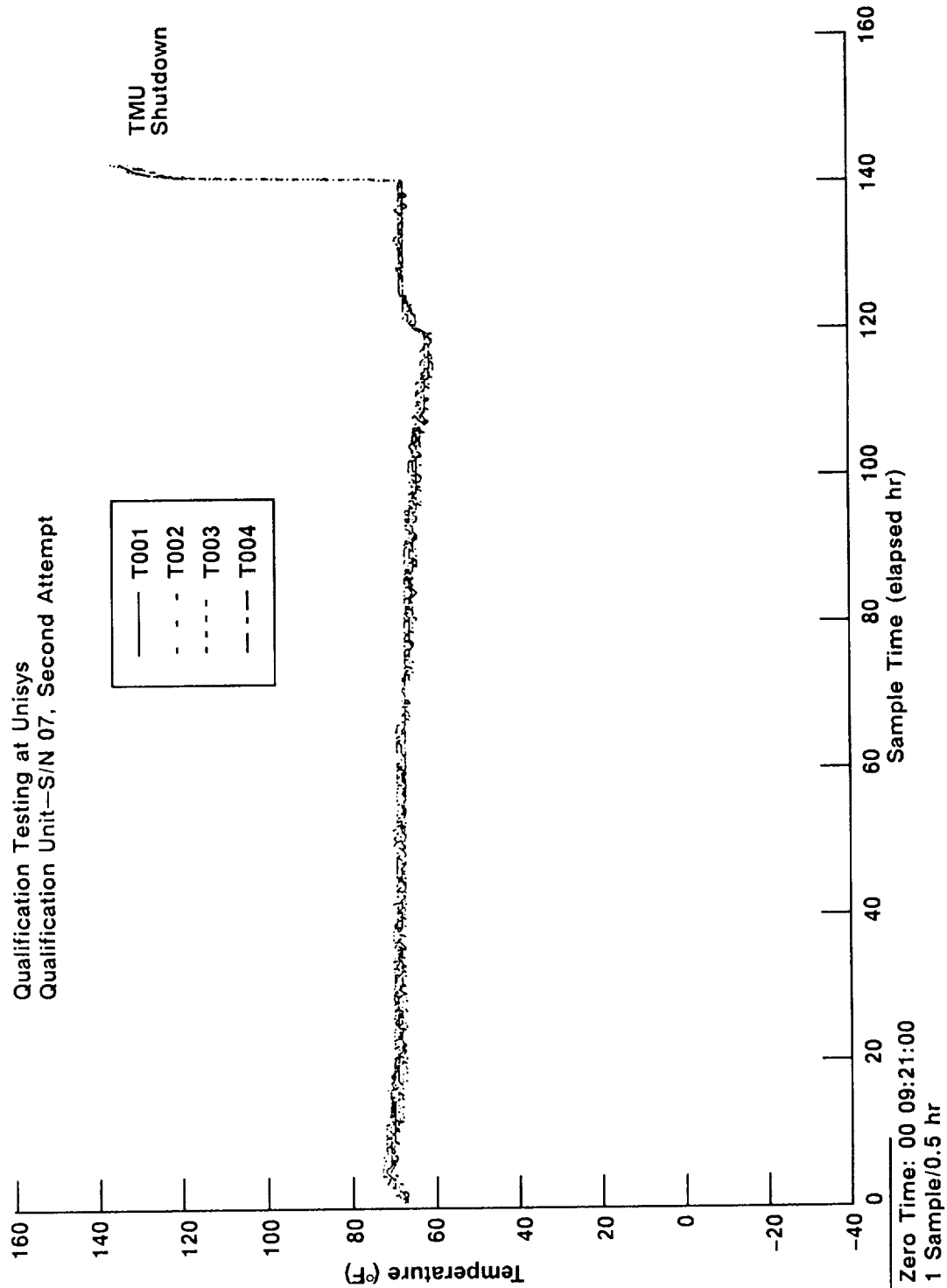


Figure 8. TMU Temperature Response Versus Time—High-Temperature Failure

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plot. The applied temperature of 150°F caused an internal electronic failure in each TMU. This failure caused each TMU to go into a continuous-triggering mode, filling each TMU memory module. This failure was similar to the failure that occurred at Wyle Laboratories during the first qualification test, indicating that the QSI internal TMU improvement was not sufficient. Because the TMUs failed due to the heat conditioning, qualification testing per CTP-0097 was terminated.

Summary. As a result of the termination of the qualification testing (due to the high-temperature shutdown and data collection errors), the transportation testing was incomplete. The functional tests were not performed, and none of the objectives of CTP-0097 were adequately addressed during the Unisys test.

6.2.3.1 Conclusion. The results of this test support the conclusion that the corrective actions taken by the vendor to eliminate high-temperature shutdowns were ineffective.

6.2.4 Testing for Engineering Evaluation Only

On 6 Dec 1989, TMU testing at Unisys was restarted for engineering evaluation only. The purpose of this testing was to determine the TMU vibration and temperature measuring accuracy at a variety of temperatures.

The tests consisted of sine dwell and shock testing at a range of temperatures, designed to simulate the transportation testing outlined in Section 6.1.2.1. The sine dwells were applied at approximately 10 Hz and 1.5 g for approximately 1 min. The shocks were half sine waves at approximately 2.0 g with a 0.08-sec duration. This testing was conducted at the following temperatures, listed in the sequence that they were tested: 130°, 140°, 150°, 70°, and -32°F.

Appendix E shows Unisys control input shock and dwell vibration plots, TMU response data (tabular form), and percent error calculations. Calculations were made using peak-to-peak values from the Unisys control input shock wave plots and the TMU tabular response data. Two shocks were used (at each temperature measurement) for the shock test comparison. Sine dwell plots were compared to the TMU tabular data.

Shock Tests. Results of the calculations from the shock tests are shown in Table 3. None of the TMU measured shock levels were within the specified tolerance of ±10 percent. Measured shock level errors decreased as temperatures increased.

The shock pulse inputs at 130°F were above the TMU cutoff frequency of 30 Hz. These inputs were at 37 Hz and above, and the TMU internal 30-Hz band pass filter eliminated all data above 30 Hz. This resulted in large differences between the input and TMU measured levels, and gave negative percent errors.

**Table 3. Shock Test Comparison--Shaker Table Control
Input Vibration Compared to TMU Measured Response Vibration**

<u>Temperature (°F)</u>	<u>Shock No. 1 Error (%)</u>	<u>Shock No. 2 Error (%)</u>	<u>Average Error (%)</u>
-32	49.8	44.2	47.0
70	22.7	19.2	21.0
130	-8.7	-10.7	-9.7
140	11.9	13.2	12.5
150	7.1	16.6	11.8

The levels measured at 70° and 140°F indicate that the TMU would have had an average error between 12.5 and 21 percent at 130°F, if the cutoff frequency had not been exceeded.

Except for the testing at 130°F, the TMU measurement errors were positive. The positive errors were a result of the TMUs measuring levels that were higher than what was actually input to the accelerometers.

Sine Dwell Tests. Results of the calculations from the sine dwell tests are shown in Table 4.

**Table 4. Sine Dwell Vibration Comparison--Shaker Table
Control Input Vibration Compared to TMU Measured
Response Vibration**

<u>Temperature (°F)</u>	<u>Sine Dwell No. 1 Error (%)</u>	<u>Sine Dwell No. 2 Error (%)</u>	<u>Average Error (%)</u>
-32	17.8	23.7	20.8
70	-2.9	-2.9	-2.9
130	-4.2	NA	-4.2
140	-7.3	-7.7	-7.5
150	-12.9	-12.5	-12.7

Sine dwell testing at 70°, 130°, and 140°F were the only temperatures that gave results within the specified allowable ± 10 percent error. These errors were -2.9, -4.2, and -7.5 percent, respectively.

TMU measured responses for vibration testing at all other temperatures were not within the specified allowable ± 10 percent of the input vibrations.

TMU Measured Zero Drift. The TMU measurements from the -32°F series of tests show a large zero drift to the positive side. Figure 9 shows that the TMU at rest measured an approximately 0.5-g level at the low temperature. This condition was determined to be unacceptable. Error calculations were performed with peak-to-peak values, and were not affected by the drift error.

Summary. Results from the additional engineering evaluation showed that the TMU did not perform to the requirements of the following documents: STW3-3662, CDW2-3454, TWR-17049 Rev A, nor the qualification testing of CTP-0097.

6.2.4.1 Conclusion. This test demonstrated that TMU vibration measurements are not within specified tolerances, and that TMUs are temperature sensitive because of decreased accuracy at high and low temperatures. Because the TMU measured shock levels were higher than the input levels, it is likely that all TMU measured shock levels are higher than what occurs at the accelerometers.

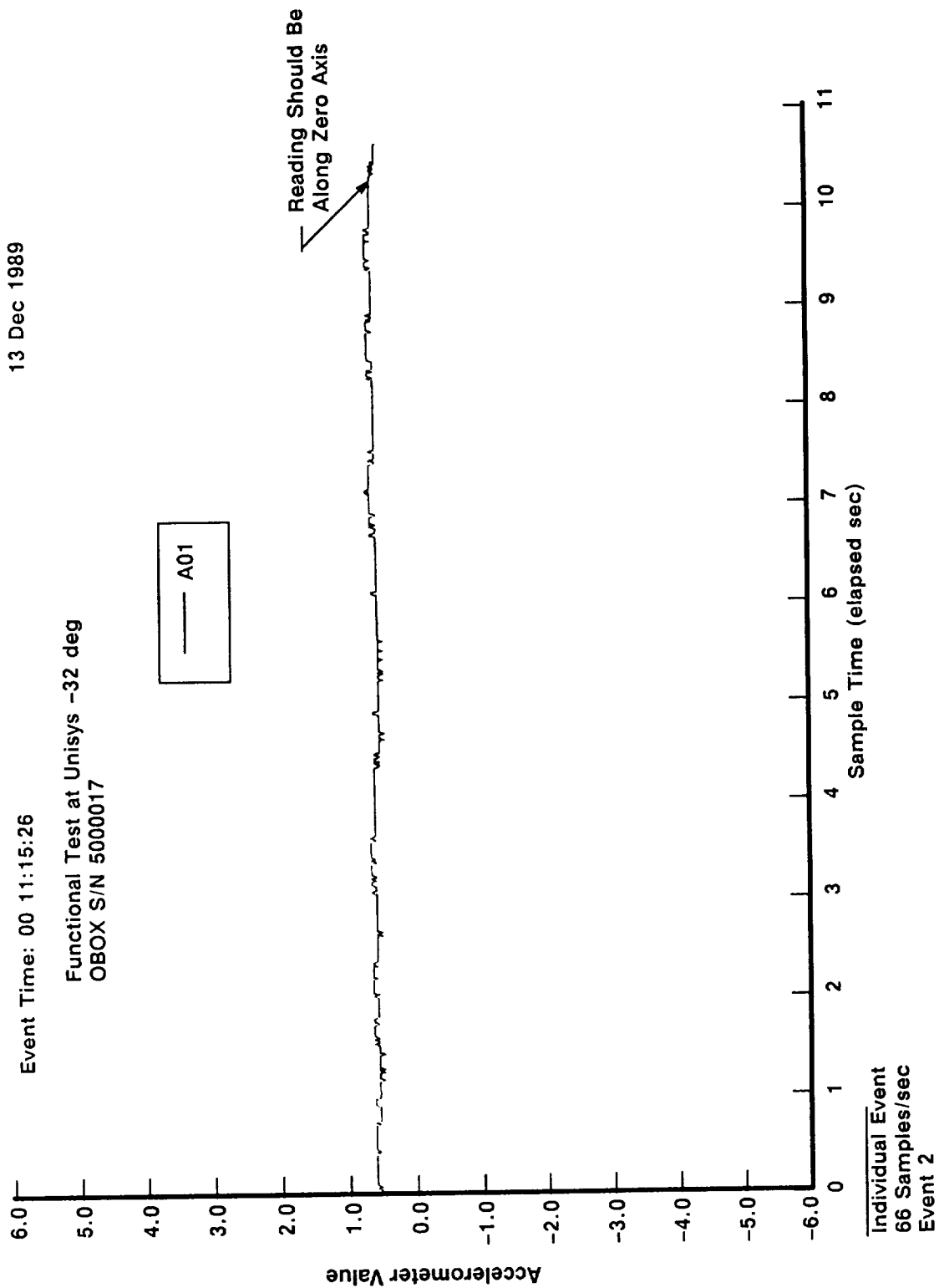


Figure 9. TMU Measure g-Level Versus Time—Cold Temperature Zero Drift

A026056a

APPLICABLE DOCUMENTS

<u>Document No.</u>	<u>Title</u>
CDW2-3454	Performance, Design, and Verification Requirements Instrumentation Systems--Railcar Model Designator P77-0480
CPW1-3600	Prime Equipment Contract End Item (CEI) Detail Specifications
CTP-0097	Transportation Monitor Unit Qualification Test Plan
DPD 400	Data Procurement Document
SL-E-0002	NSTS Specification, EMI Characteristics, Requirements for Equipment
SW-E-0002	Space Shuttle GSE General Design Requirements
STW3-3662	Transportation Monitor Unit Product Specification
TWR-15723	Redesign D&V Plan
TWR-17049 Rev A	Transportation Monitoring System SRM Railcars
SE-019-049-2H	Solid Rocket Booster Vibration, Acoustic and Shock Design and Test Criteria
<u>Military Standards</u>	
MIL-STD-45662	Calibration System Requirements
MIL-STD-461A	Electromagnetic Interference Characteristics
MIL-STD-462	EMI Test Procedures
<u>Drawing No.</u>	
8U76218	Transportation Monitoring Unit--Kit

APPENDIX A

Wyle Laboratories TMU Test Report No. 53976

TEST REPORT

WYLE

LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP
WESTERN OPERATIONS, NORCO FACILITY

REPORT NO. 53976
OUR JOB NO. DE 53976
CONTRACT NAS8-30490
YOUR P. O. NO. 9MG021

MORTON THIOKOL, INC.
Space Operations
Highway 83
Brigham City, Utah 84302-0707

72 - Page Report

DATE 26 June 1989

This is to certify that the enclosed test data sheets contain true and correct data obtained in the performance of the test program as set forth in your purchase order.

Test methods, results, and equipment used are recorded on these data sheets.

Where applicable, instrumentation used in obtaining this data has been calibrated using standards which are traceable to the National Bureau of Standards.

SUMMARY:

Two SRM Segment Transportation Monitoring Units, Prototype, Units 1 and 2, were submitted for test in accordance with Morton Thiokol Document No. CTP-0097, Revision B, dated 12 January 1989. The specimens completed shock testing in the longitudinal axis at -20 and +70F, and transportation vibration as recorded on the test data sheets. As documented in Notice of Deviation No. 1, Test Unit No. 1 suffered structural damage during ambient temperature transportation dwell test at the first mode. During the high temperature transportation vibration test, both specimens stopped functioning at approximately +150F. At the direction of Morton Thiokol, testing was discontinued. (See Notice of Deviation No. 2.) Test setup is shown in Photograph 1, and the broken mounting plate of Test Unit No. 1 is shown in Photograph 2.

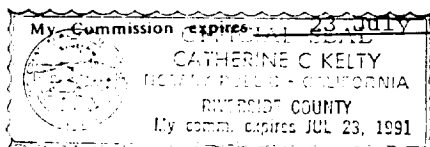
STATE OF CALIFORNIA } ss.
COUNTY OF RIVERSIDE

W. D. Peters, being duly sworn,
deposes and says: That the information contained in this report is the result of
complete and carefully conducted tests and is to the best of his knowledge true
and correct in all respects.

W.D. Peters

SUBSCRIBED and sworn to before me this 27th day of June, 19 89

Catherine C. Kelty
Notary Public in and for the County of Riverside, State of California



W-867A

DEPARTMENT DYNAMICS/ENVIRONMENTAL

DEPT. MGR. J. J. Anderson

TEST ENGINEER C. C. Lee
C. C. Lee

REGISTERED
PROFESSIONAL
ENGINEER

DCAS-QAR VERIFICATION

QUALITY ASSURANCE L. Housteau
L. Housteau

ORIGINAL PAGE IS
OF POOR QUALITY

DATA SHEET

Customer MORTON THIOKOL Job No. 53976
Date 2-27-88

Specimen TRANSPORTATION UNITS

RECEIVING INSPECTION

No. of Specimens Received: TWO

Record identification information exactly as it appears on the tag or specimen:

Manufacturer MORTON THIOKOL

Part Numbers PROTOTYPE

How does identification information appear: (name plate, tag, painted, imprinted, etc.)

Serial Numbers: * UNIT 1
2

Examination: Visual, for evidence of damage, poor workmanship, or other defects, and completeness of identification.

Inspection Results: There was no visible evidence of damage to the specimens unless noted below.

* If additional space is required for serial numbers, use an additional page, or reference first functional test data sheet (if applicable).

Inspected By M. L. Ch
Sheet No. _____ of _____
Approved C. C. Lee Date: 2-27-89

DATA SHEET

VIBRATION
TEST TITLE SINE / RESONANT DWELLS

CUSTOMER M.T.I. Job No. 53976
 Specimen T.M.U. Date Started 2-28-85
 Part No. PROTOTYPE Serial No. UNITS I & II Date Comp. 4-5-89
 Spec. MTI TP CIP-0097 Par. 8 Photo YES Amb. Temp. 70°F ± 10°

THE TEST SPECIMENS WERE MOUNTED TO
 "C" CHANNEL USING SHOCK MOUNTS PROVIDED
 BY CUSTOMER IN TURN WERE SECURED
 TO AN ELECTRO DYNAMIC EXCITER
 TEMPERATURE CONDITIONED FOR A MINIMUM
 OF FOUR HOURS, AND SUBJECTED TO
 THE FOLLOWING AXIS AND TEST LEVELS

SINUSOIDAL VIBRATION - LONG AND TANGENTIAL

5 TO 2000 TO 5 HZ

5 - 130 HZ

1.2 G's

130 - 180 HZ

.0014 "DA

180 - 2000 HZ

2.5 G's

RESONANCE DWELLS - AT THE TWO MAJOR
 RESONANCES DURING
 SINE VIBRATION

TEMPERATURES - - 20°F ± 10°

AMBIENT + 70°F ± 10°

+ 163°F ± 10°

DATA SHEET

VIBRATION
TEST TITLE SINE / RESONANT DWELLS Date 4-5-89
Customer MT.I. Job No. 53976
Specimen T.M.U. Technician Nigro
Part No. PROTOTYPE Serial No. UNITS I & II Engineer C. G. H.

TEST RESULTS:

3-6-89

DWELL #1 LONG AXIS

TEST WAS STOPPED WHEN
MOUNTING PLATE WAS
DISCOVERED BROKEN (REF. NO. NO. 1)

4-5-89

UNIT II
HOUR 0830

TEMP CONDITIONING AT
163°F OVER NITE
CUSTOMER'S SPECIMEN
FAIL TO RESPOND
CORRECTLY

UNIT II
HOUR 1125

TEMP CONDITIONING WAS
RESUMED ON UNIT II
STARTING AT APPROX
120 DEGREES WHEN
AT 150 DEGREES AFTER
RAISING TEMP FROM 120°F
UNIT THEN FAILED
AT ABOUT 45 MIN E.T.
APPROX.

(REF. NO. NO. 2)

DATA SHEET

Report No. 53976

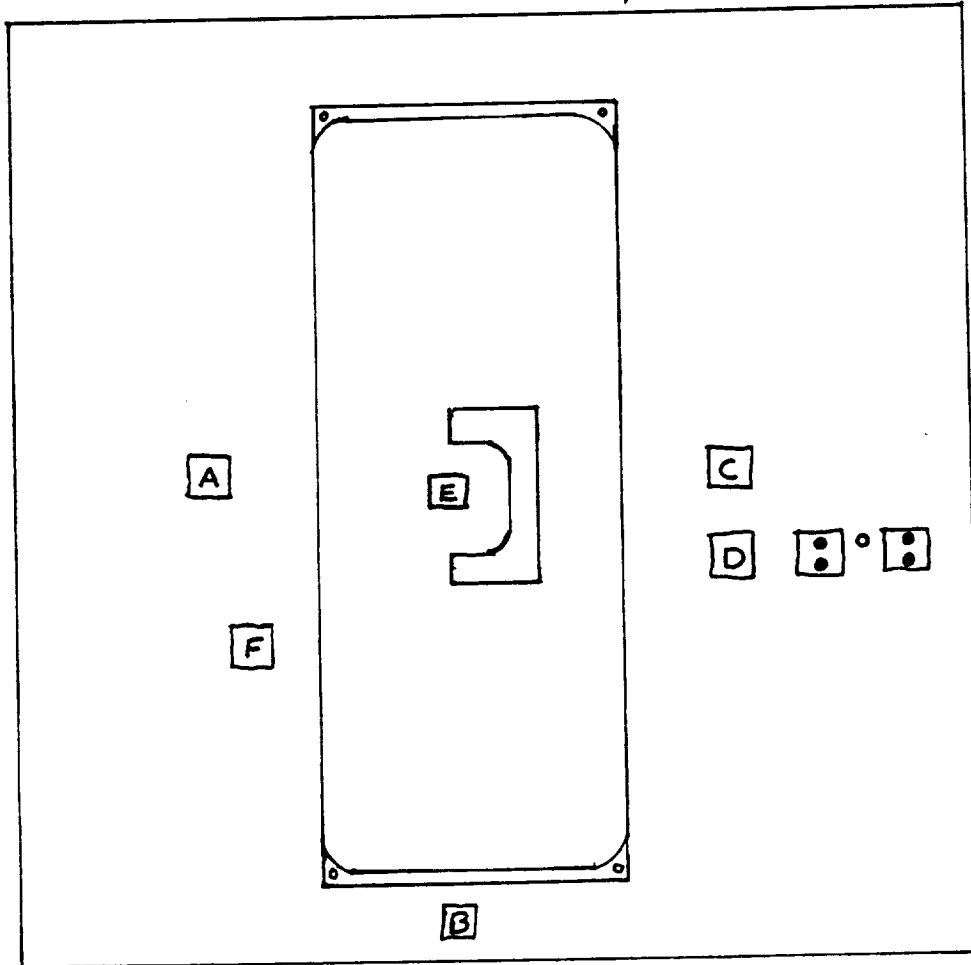
Page No. 5

TEST TITLE TRANSPORTATION ; FUNCTIONAL Date 2-28-89
Customer MORTON THIOKOL Job No. 53976
Specimen TRANSPORTATION MONITOR UNIT Technician M. OL
Part No. SEE REC INSP. Serial No. SEE REC INSP. Engineer C. G. Hu

ACCELEROMETER

(A) A001 Long	(B) A004 Long	(C) A007 Long
A002 VERT.	A005 VERT.	A008 VERT.
A003 TAN.	A006 TAN.	A010 TAN.
(E) A012 Long	(D) A009 VERT.	(F) A011 CONTROL
A013 VERT.	A014 TAN.	

Long
VERT.
TAN.



THERMOCOUPLE CUSTOMER • T001
T002
T003
T004 CONTROL 0

DATA SHEET

TEST TITLE TRANSPORTATION ; FUNCTIONAL Date 2-28-89
Customer MORTON THOMAS Job No. 53976
Specimen TRANSPORTATION MONITOR UNIT Technician M. C.
Part No. SEE REC. Insp. Serial No. SEE REC. Insp. Engineer C. C. Hu

ACCELEROMETER / S/N

A001	21161
A002	20947
A003	21509
A004	21628
A005	21387
A006	22329
A007	21412
A008	21624
A009	21650
A010	21172

A011	CONTROL	} WYLE ACCELS
A012	RESPONSE	
A013	RESPONSE	
A014	RESPONSE	

DYNAMICS SECTION
VIBRATION TEST DATA SHEET

Job No. 53976

Sheet _____ of _____

S/N 182

P/N-

Specimen Scanner / Recorder

Customer *MORTON THICKOL*

Comments

[illegible]

Report No. 53976

Page No. 7

W589 QA Form Approval LA

Signed: _____

DYNAMICS SECTION

VIBRATION TEST DATA SHEET

Customer M.T. 1.

Specimen T MJ

P/N

S/N

[illegible]

Report No. 53976

Page No. 8

W589A QA Form Approval *[Signature]*

Signed: C.C. Lu

DATE 3-6-89
Job No. 53976
Technician NISPORIC
Engineer C.C. Lee

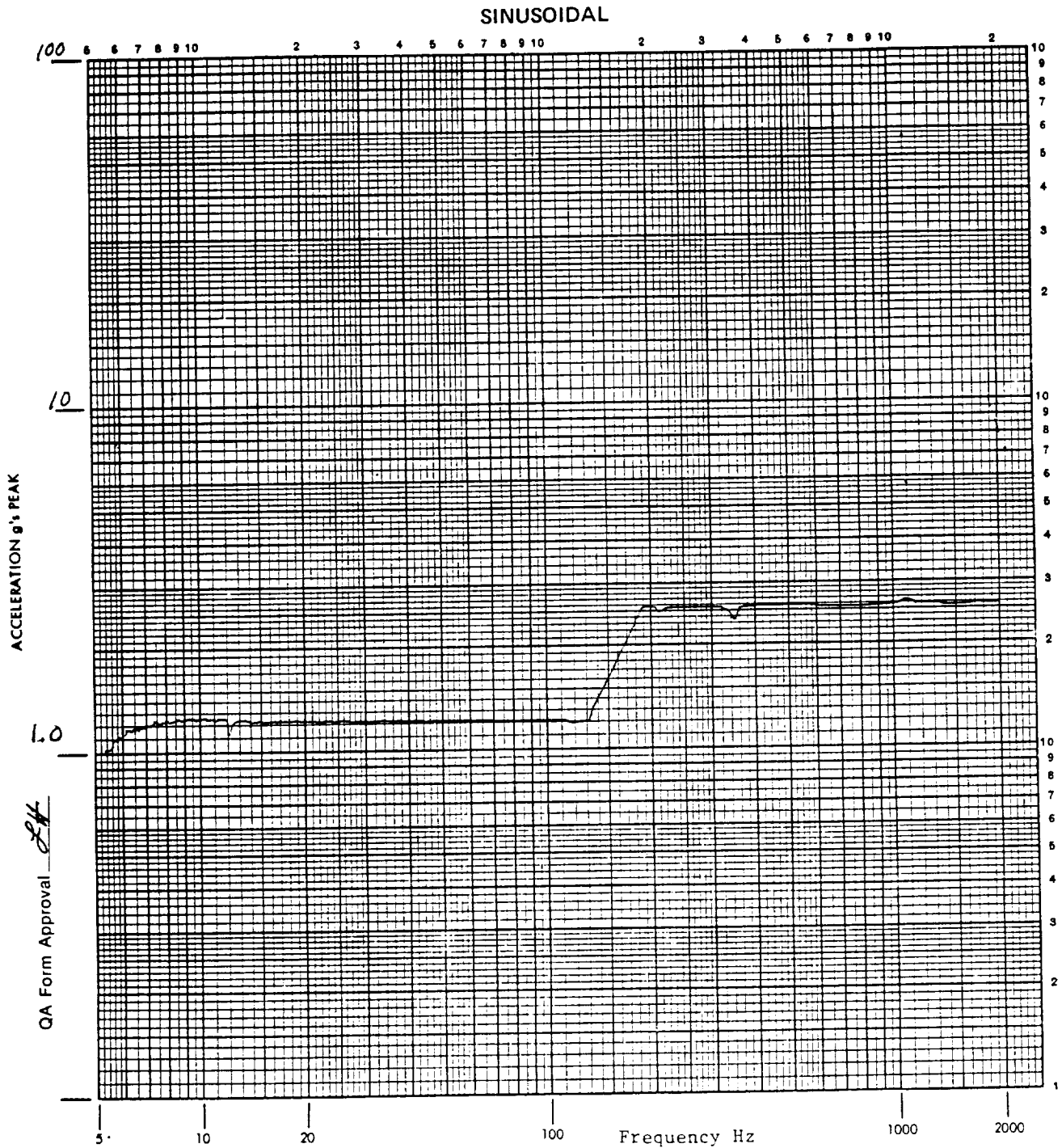
W-985 QC Form Approval 5/15

DATA SHEET

TEST TITLE RESONANT DWELLS DATE 4-4-89
Customer M.T.I. Job No. 53926
Specimen T.M.U. Technician NISARIC
Part No. PROTOTYPE Serial No. UNITS 1 & 2 Engineer CCH

[illegible]

CUSTOMER MTI Job No. 53976 Date 3 MAR 89
Specimen T.M.V. specimen #1 Axis of Test Long
Accel. No. #1 Control (X) Response (X) cut. Full Scale 100
Operator M. Chen Engineer C. Chen -20°F



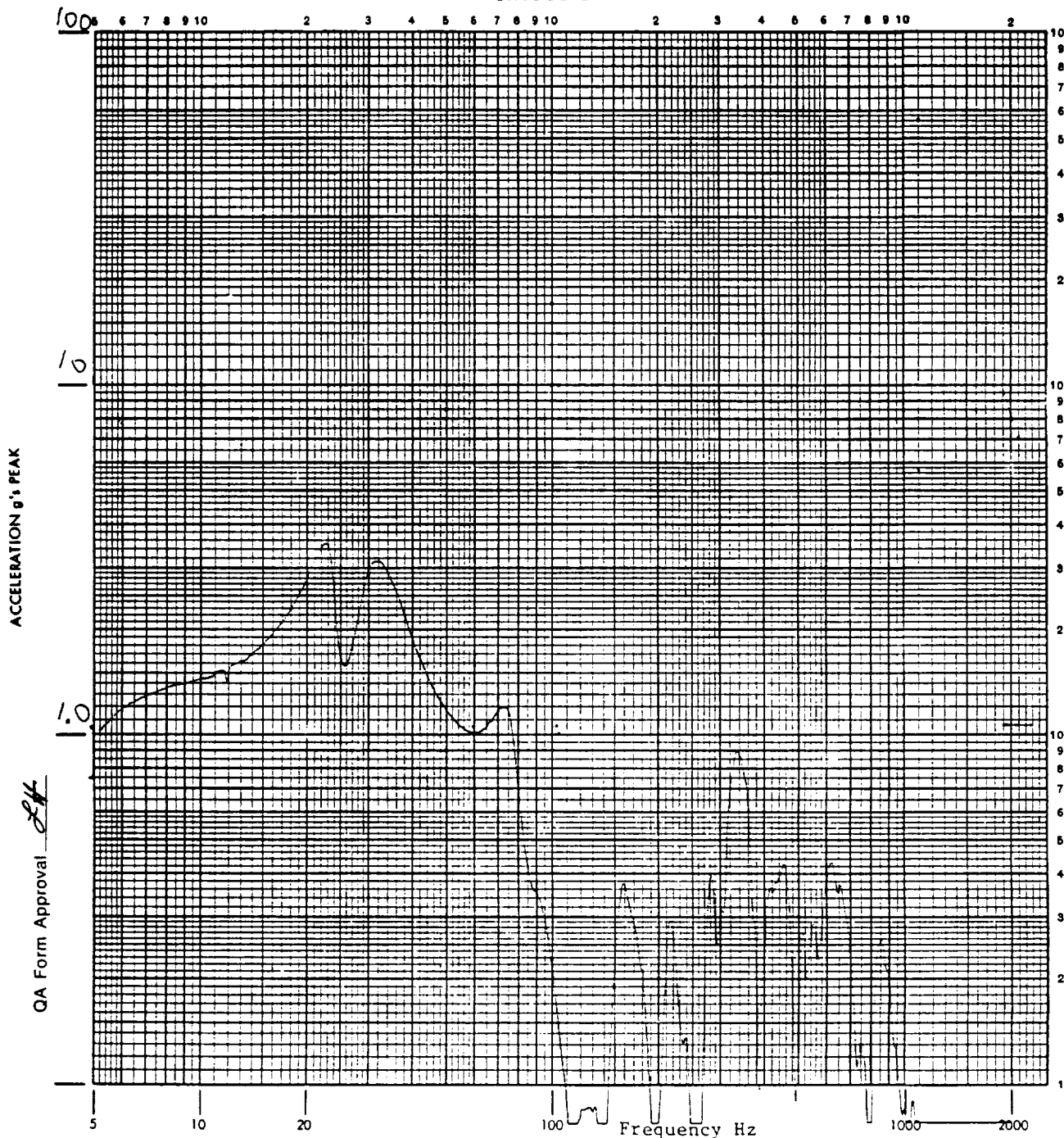
CUSTOMER M.T.I. Job No. 53976 Date 3 MAR 89

Specimen T.M.V. SPECIMEN #1 Axis of Test Long

Accel. No. #2 (LONG) Control () Response (X) Full Scale 100 g

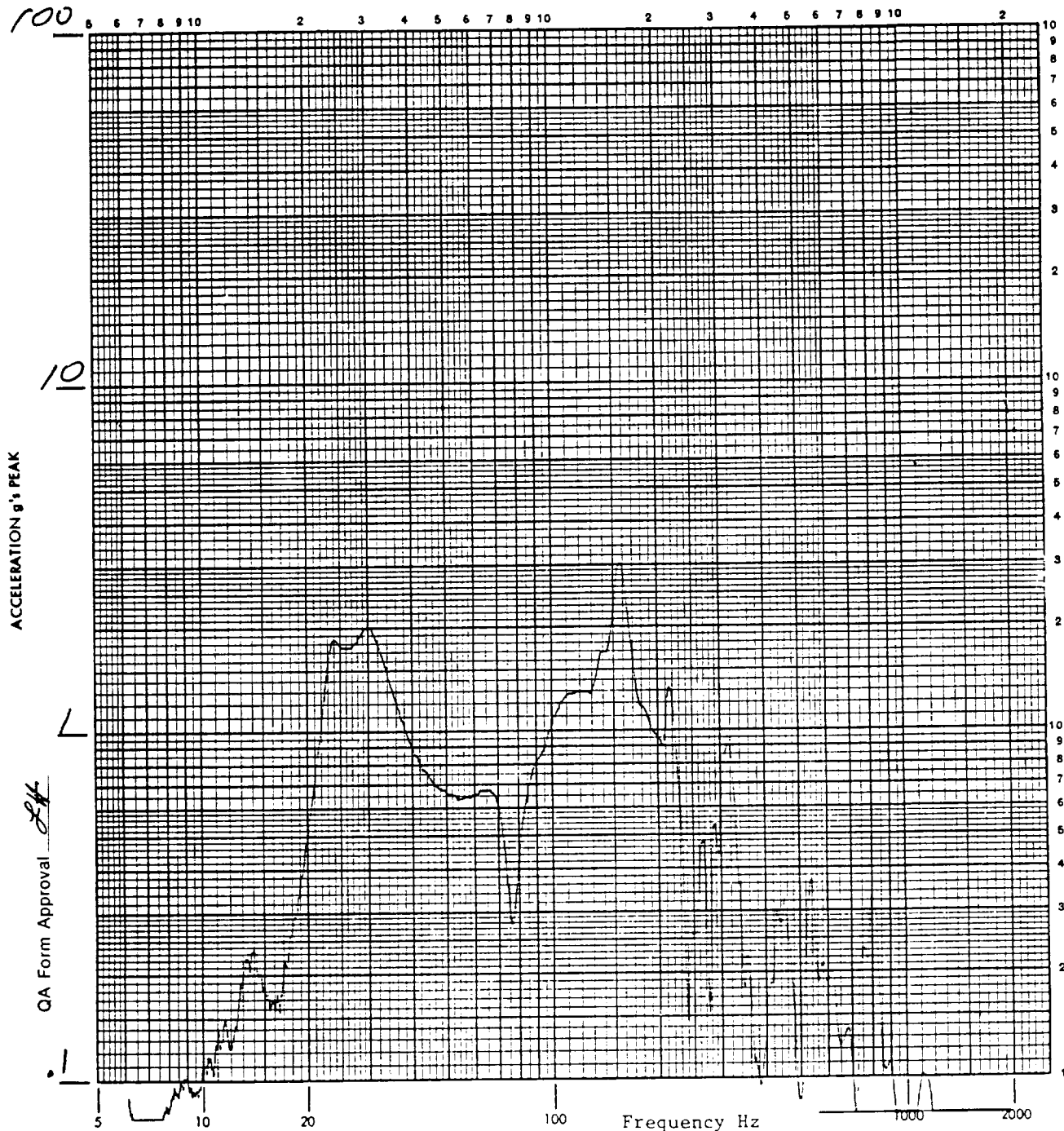
Operator MA Engineer CC -20°F

SINUSOIDAL



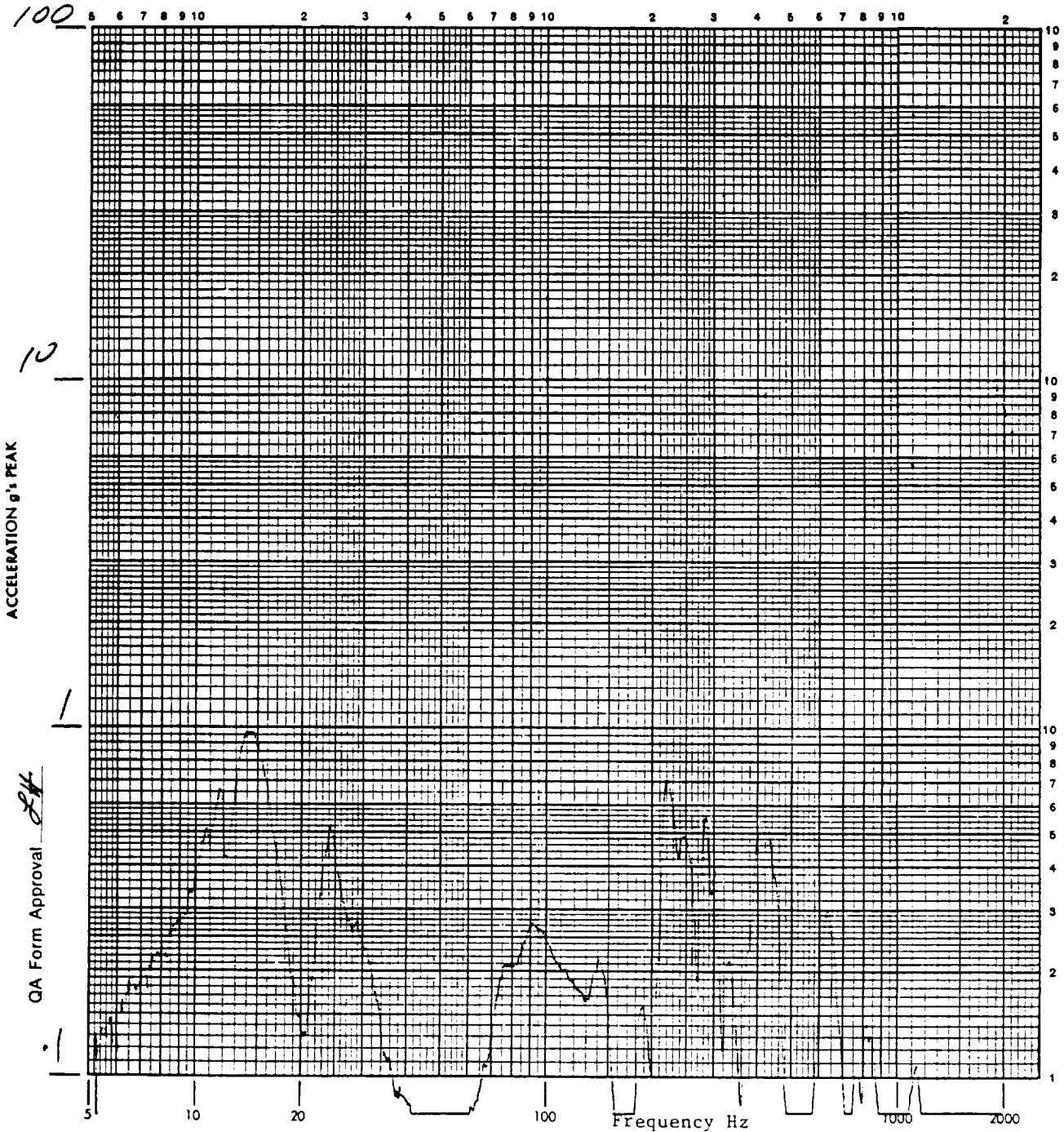
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Specimen TMU Axis of Test LONG
Accel. No. 3 (~~VERT.~~) Control () Response (x) Full Scale 100
Operator MM Qls Engineer CC Lm -20°C

SINUSOIDAL



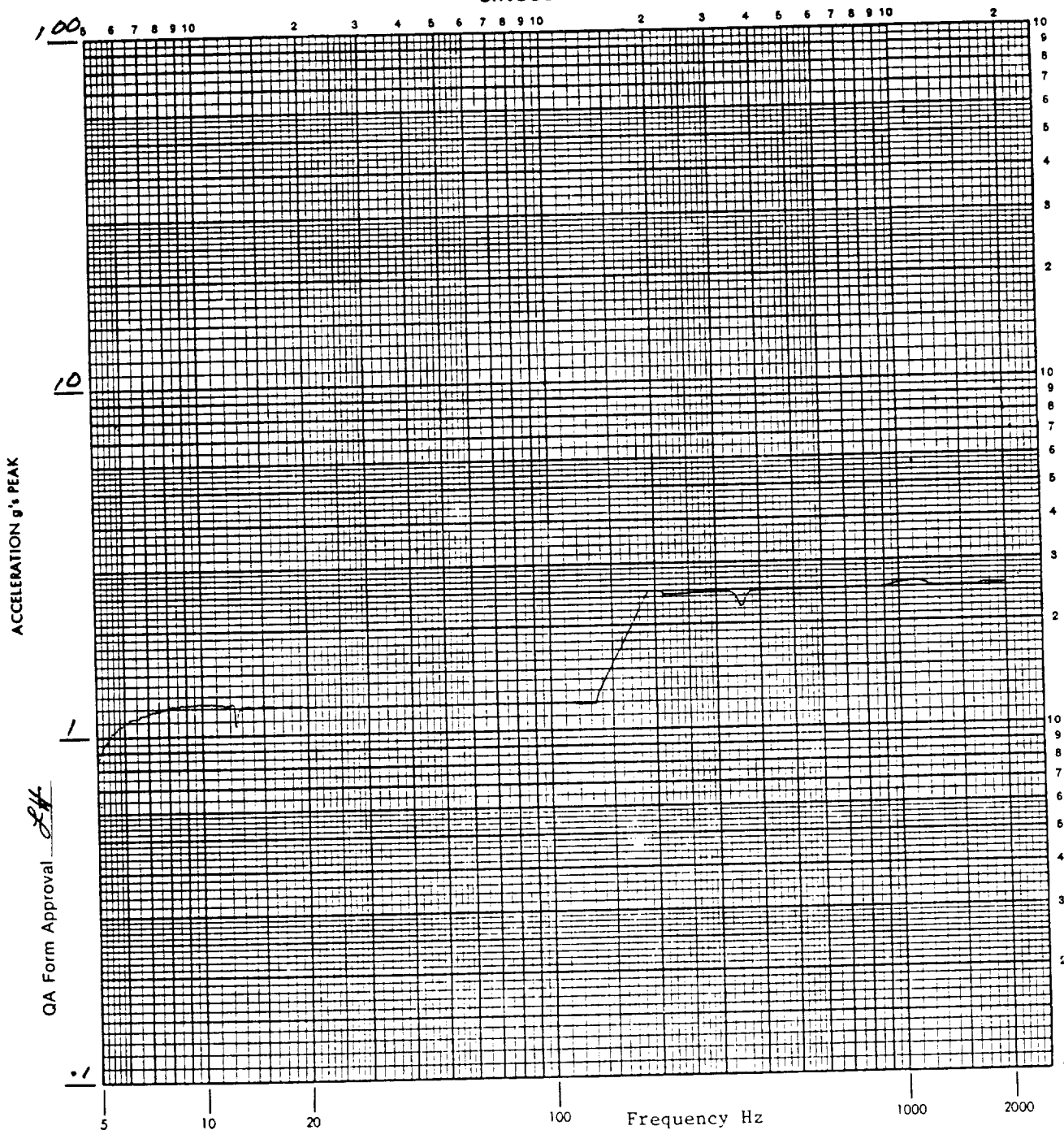
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Specimen TMV UNIT #1 Axis of Test LONG
Accel. No. 4 Control () Response (X) Full Scale 100 g
Operator MCN Engineer CCJ -20°F

SINUSOIDAL



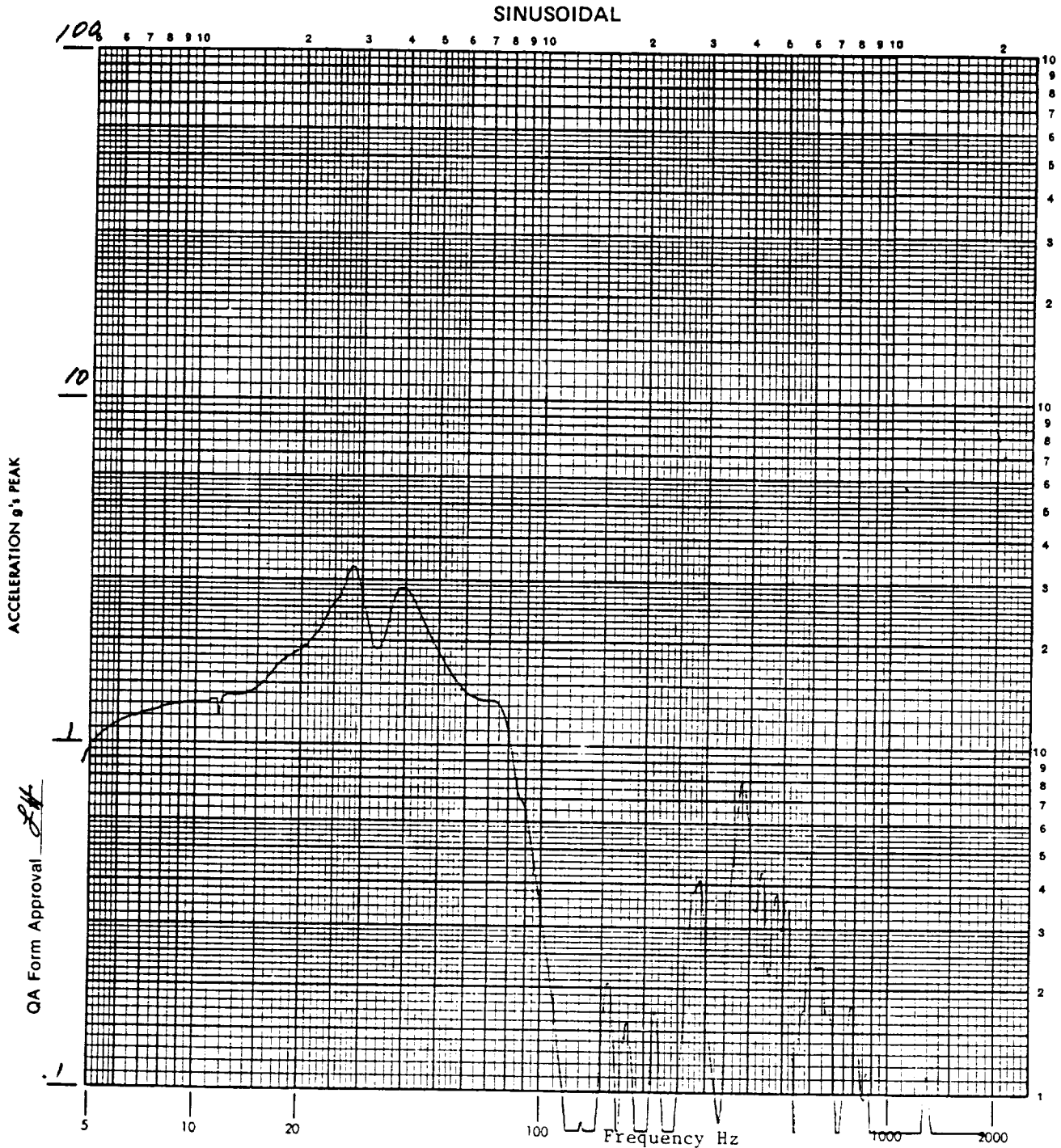
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Specimen T.M.V. UNIT # 2 Axis of Test Long
Accel. No. 1 Control (☒) Response () Full Scale 100 g
Operator M. Qu Engineer C. Chen -20°F

SINUSOIDAL

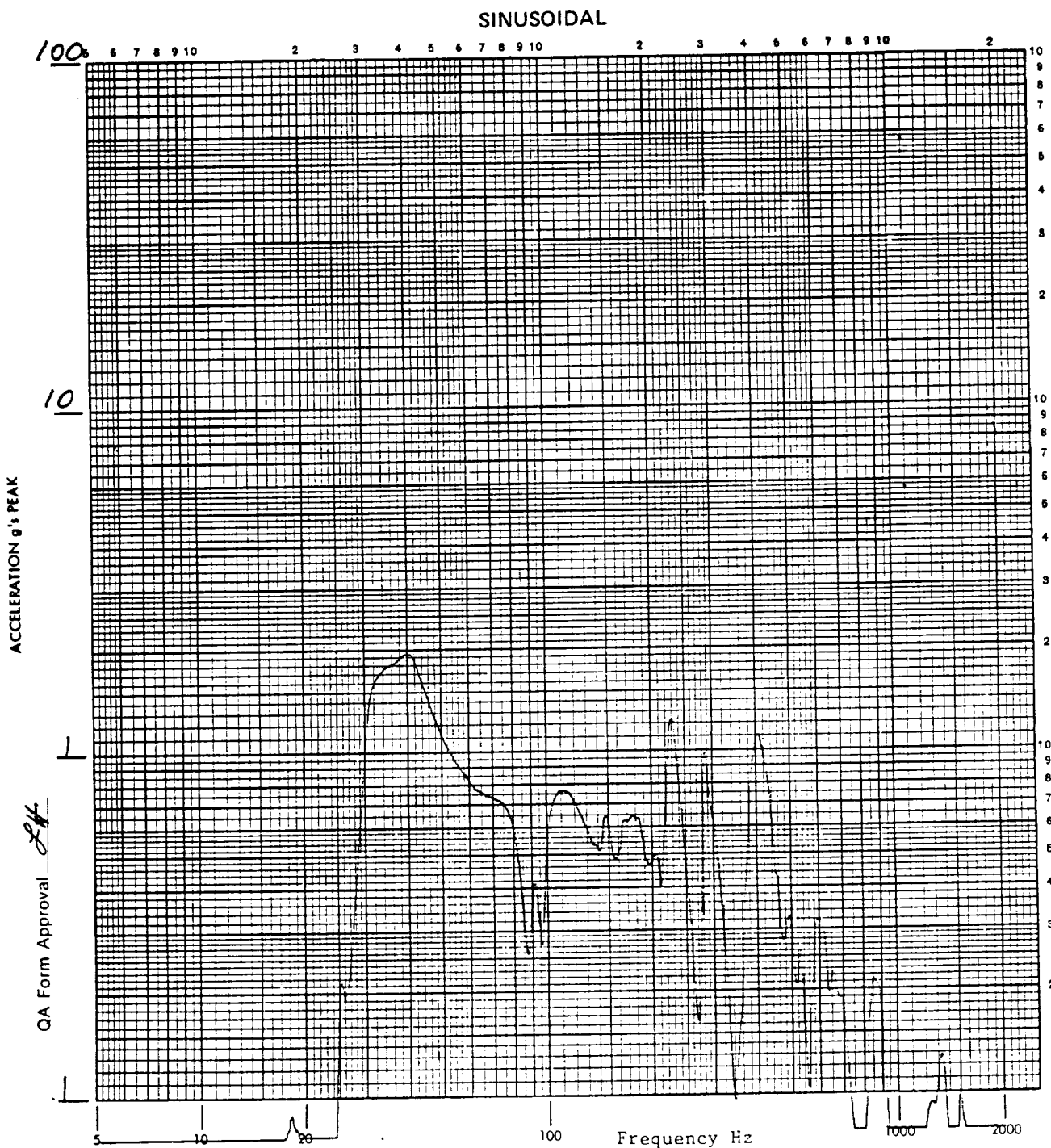


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CUSTOMER MTI Job No. 53976 Date 3-3-89
Specimen T.M.V. UNIT #2 Axis of Test Long
Accel. No. 2 Control () Response (☒) Full Scale 100 g
Operator PJW Engineer CCM
-20°C

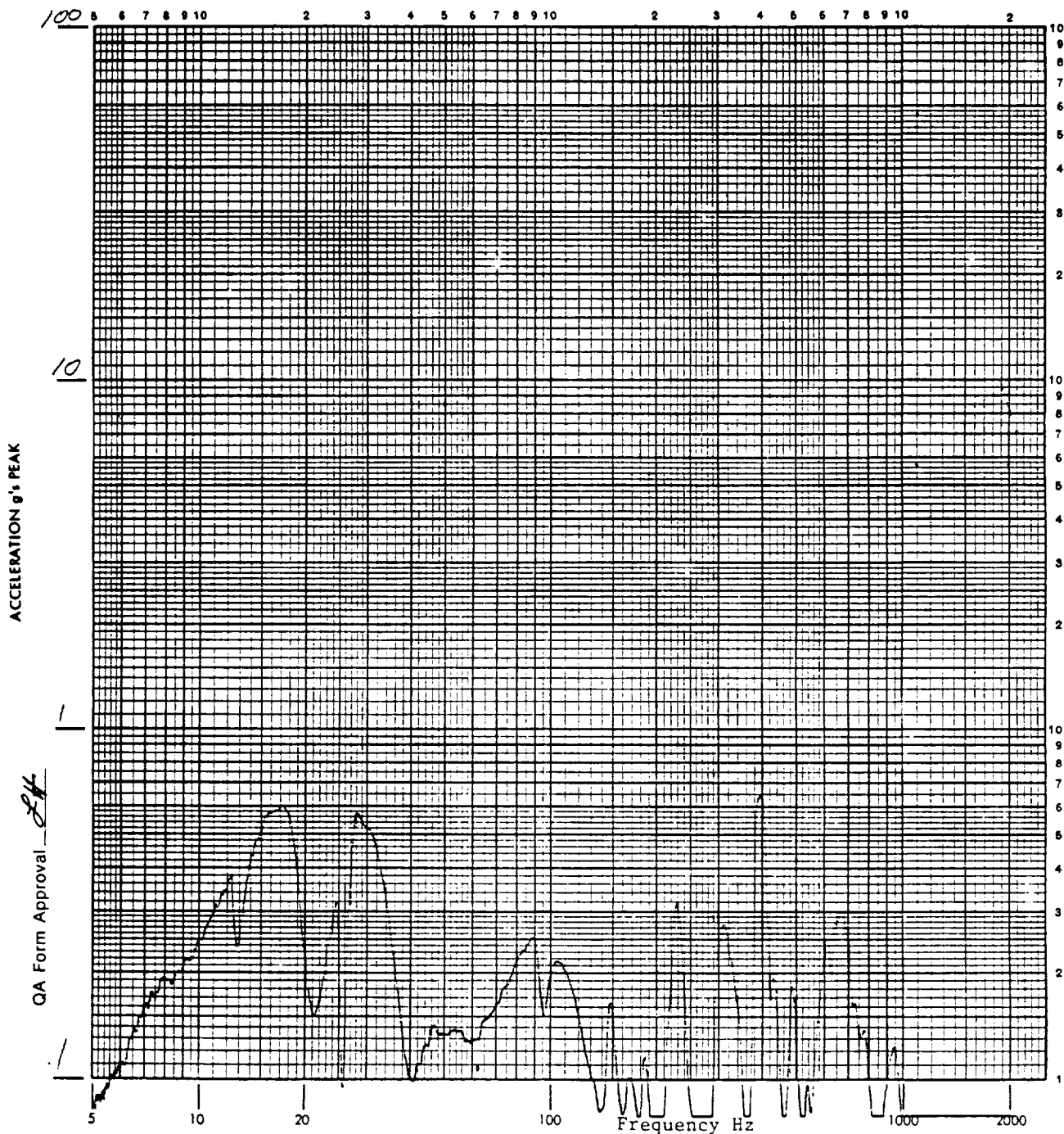


CUSTOMER Morton THIOKOL Job No. 53976 Date 3-3-89
Specimen T.M.V. UNIT #2 Axis of Test LONG
Accel. No. 3 Control () Response (X) Full Scale 100
Operator MC Engineer CCM -20°F



CUSTOMER MORTON THIOCOL Job No. 53976 Date 3-3-89
Specimen J.M.V. UNIT #2 Axis of Test LONG.
Accel. No. 4 Control () Response (✓) Full Scale 100 g
Operator M. B. Engineer C. C. Hu -20°F

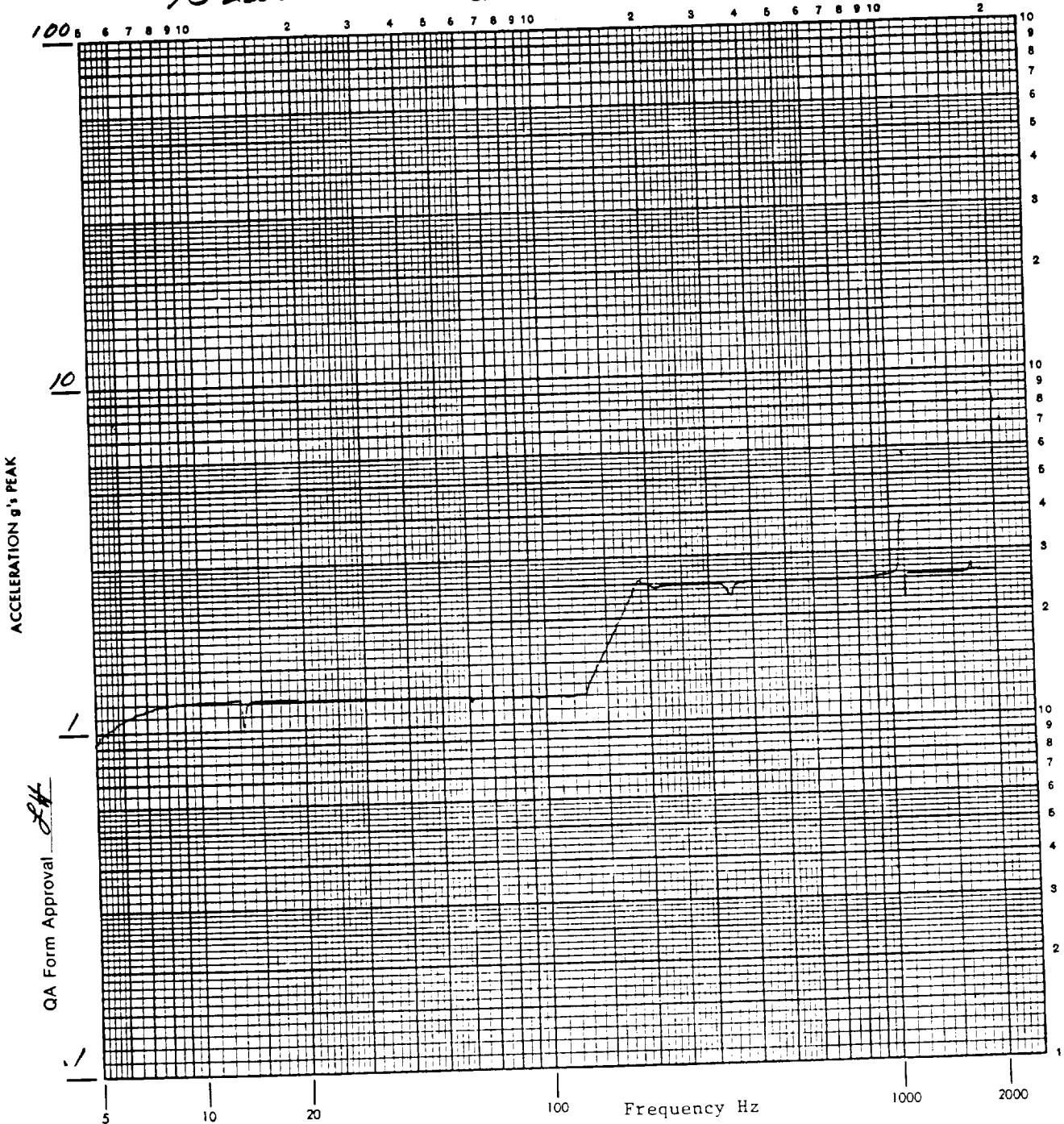
SINUSOIDAL



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CUSTOMER MTI Job No. 53976 Date 3-6-89
Specimen UNIT # 2 Axis of Test Long
Accel. No. 1 Control (☒) Response () Full Scale 100
Operator M. Olin Engineer C. L. H. AM13.

1/3 LEVEL DOWN SINUSOIDAL



CUSTOMER MTI Job No. 53976 Date 3-6-89

Specimen UNIT # 2 Axis of Test Long

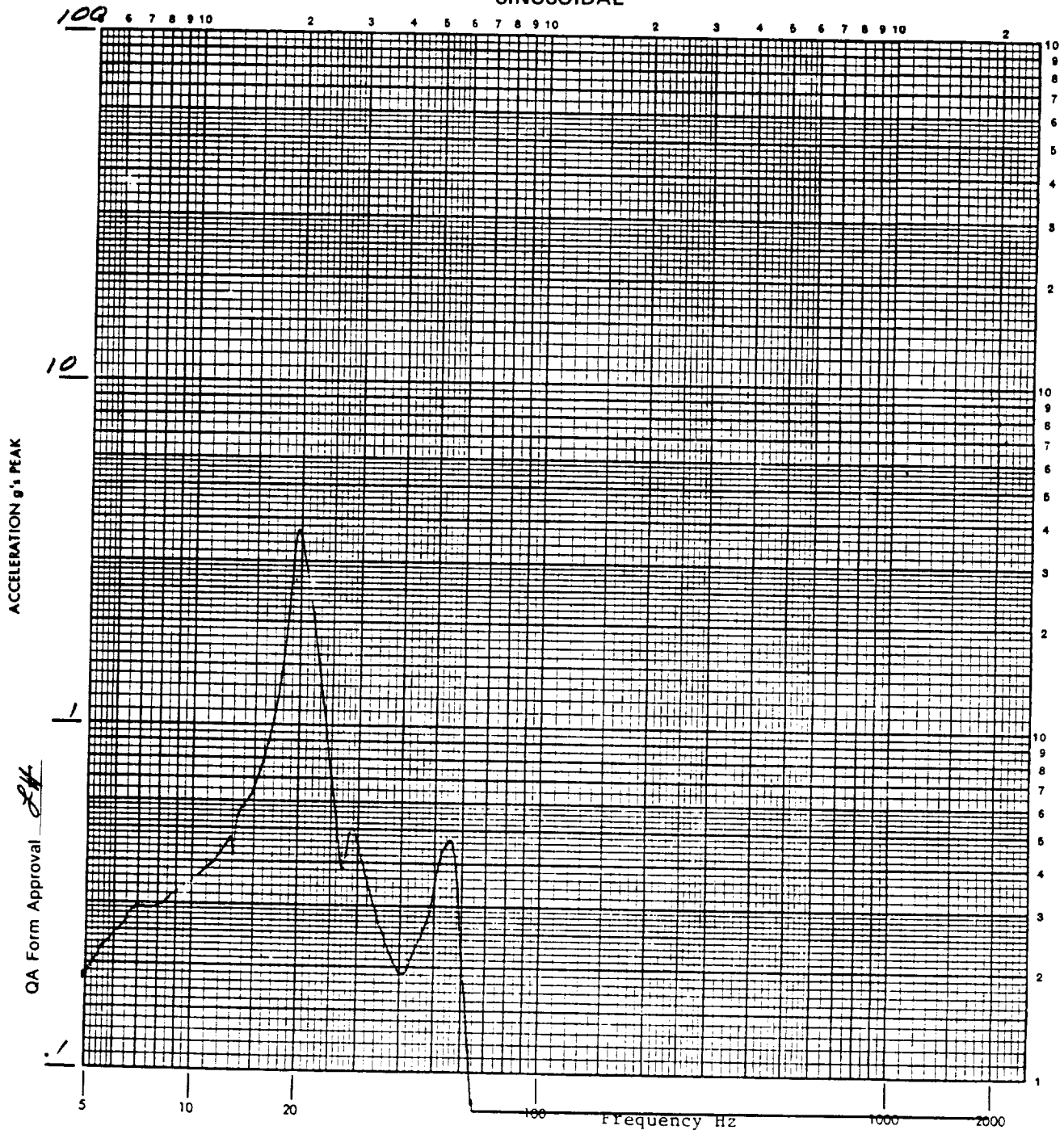
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Operator M. Ok Engineer C. Chm

1/3 Level Down

SINUSOIDAL

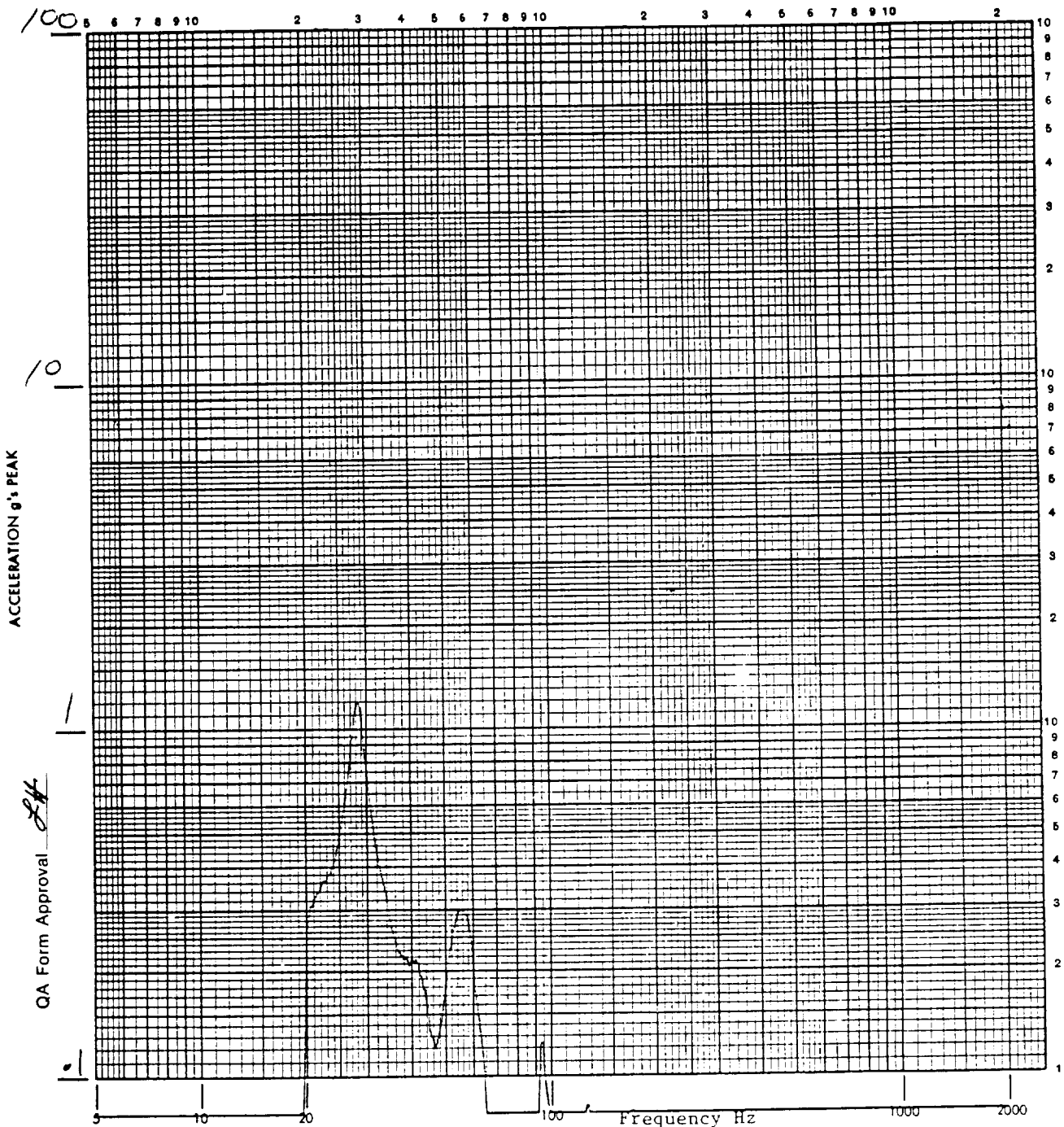
AMB.



CUSTOMER MTI Job No. 53976 Date 3-6-89
Specimen UNIT 2 Axis of Test LONG
Accel. No. 3 Control () Response (X) Full Scale 100
Operator mol Engineer CCM

AMB

1/3 level Down SINUSOIDAL



CUSTOMER MTI

Job No. 53976 Date 3-6-89

Specimen UNIT 2

Axis of Test LONG

Accel. No. 4 Control () Response (X)

Full Scale 100 g

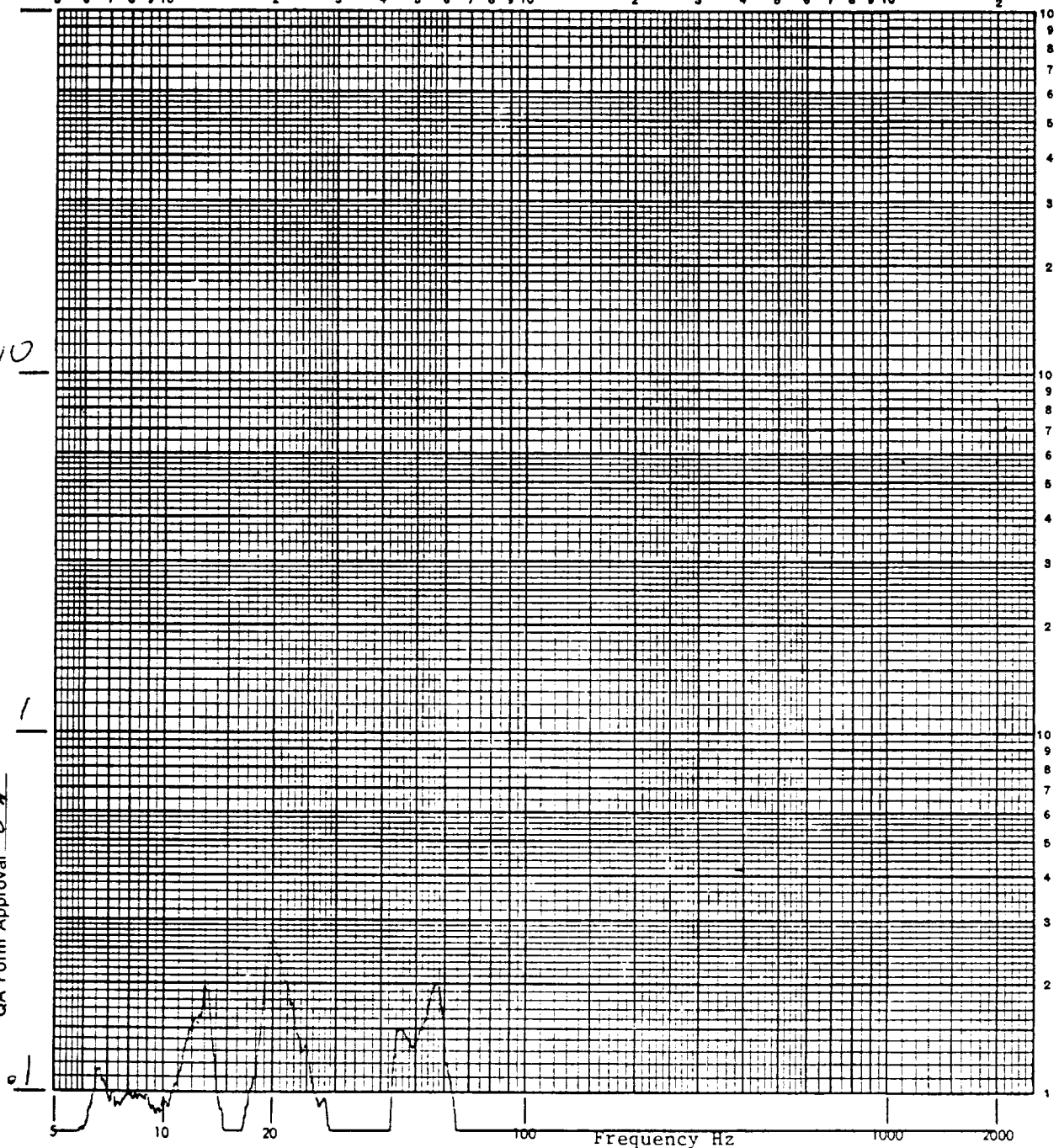
Operator M. O. Engineer C. L. H.

AMB

100 1/3 LEVEL DOWN SINUSOIDAL

ACCELERATION g's PEAK

QA Form Approval SLH



CUSTOMER MTI

Job No. 53976 Date 6-6-89

Specimen UNIT # 1

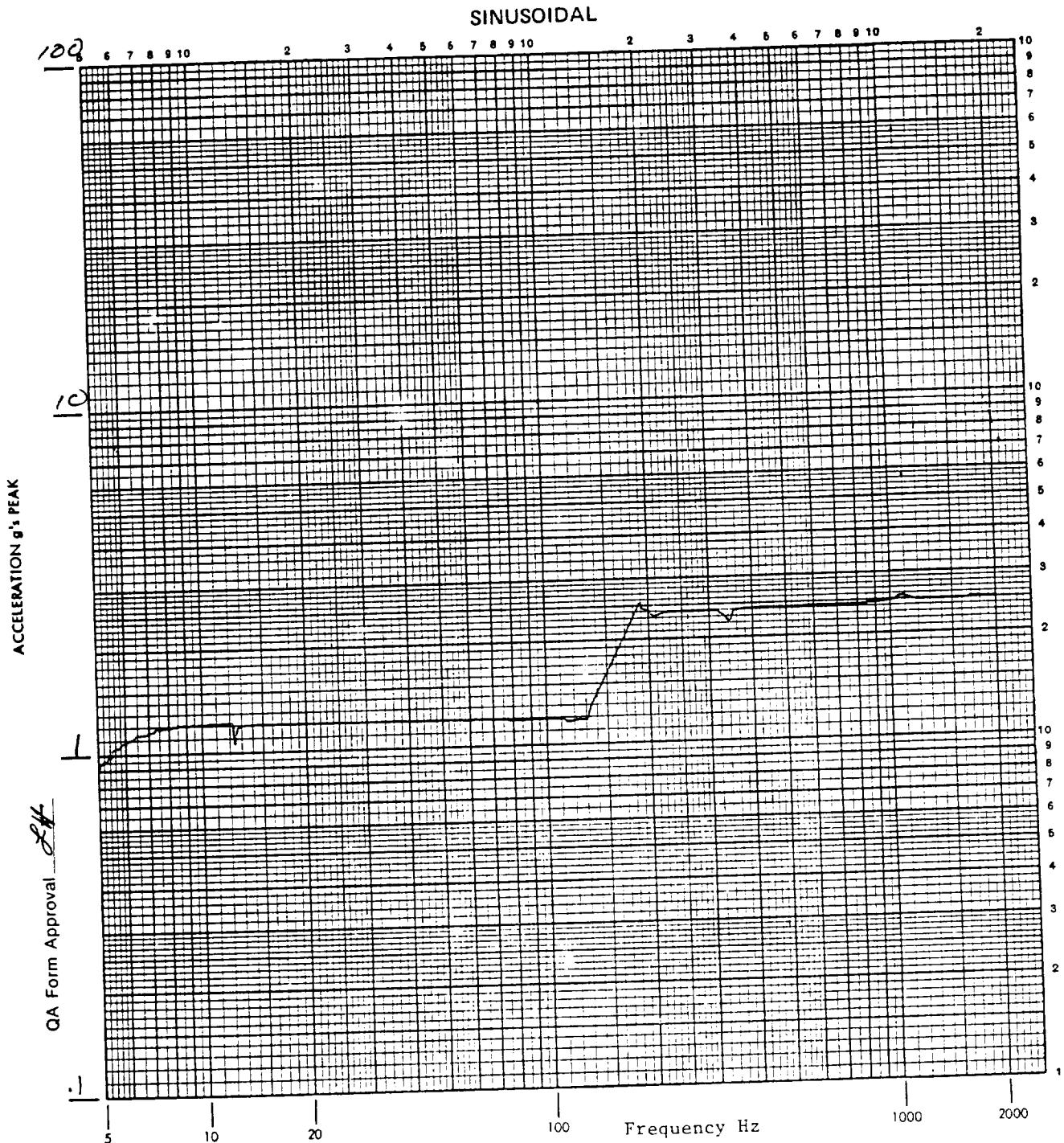
Axis of Test Long

Accel. No. 1 Control (☒) Response (☐)

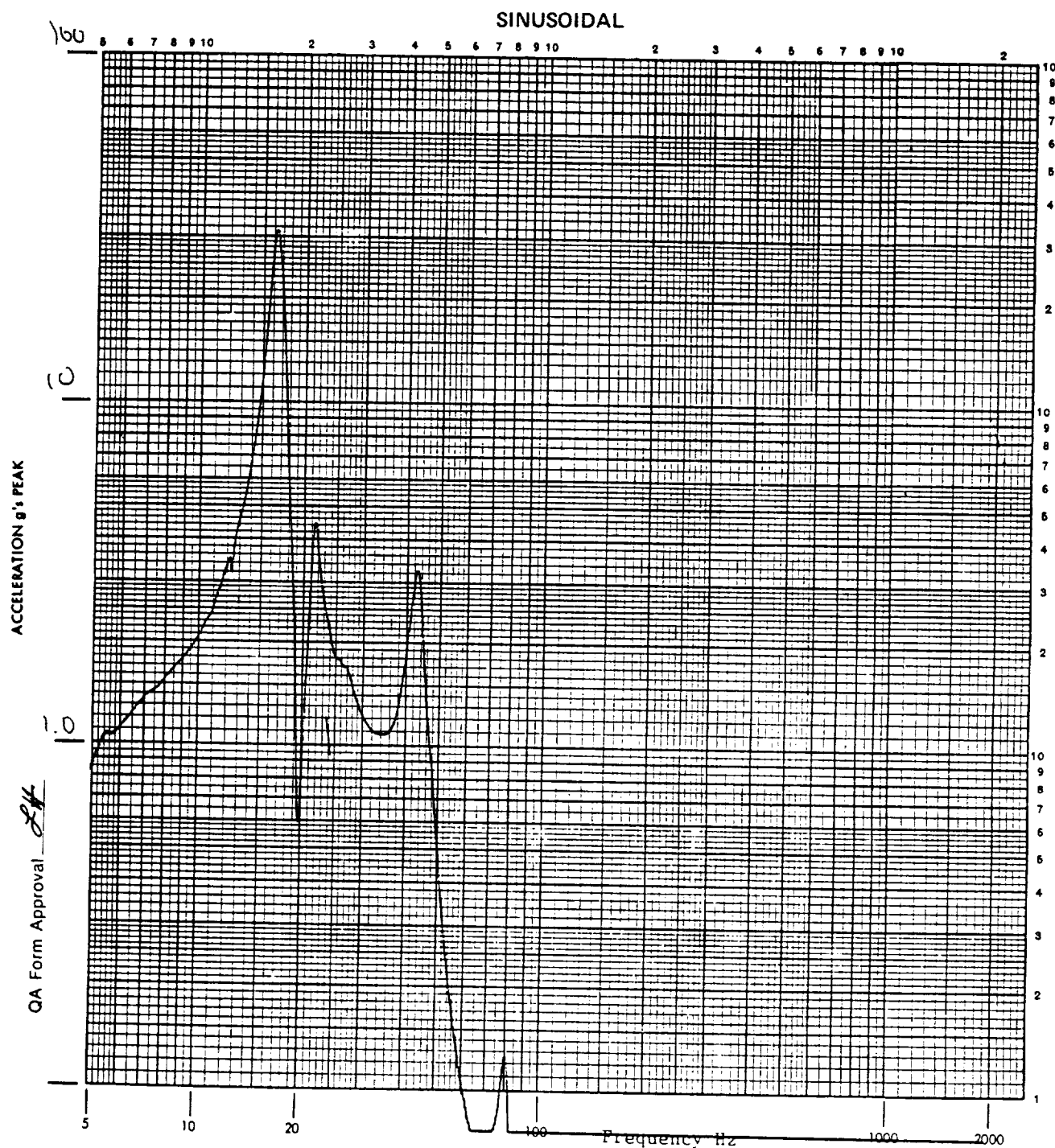
Full Scale 100 9

Operator M. Oz Engineer CCJ

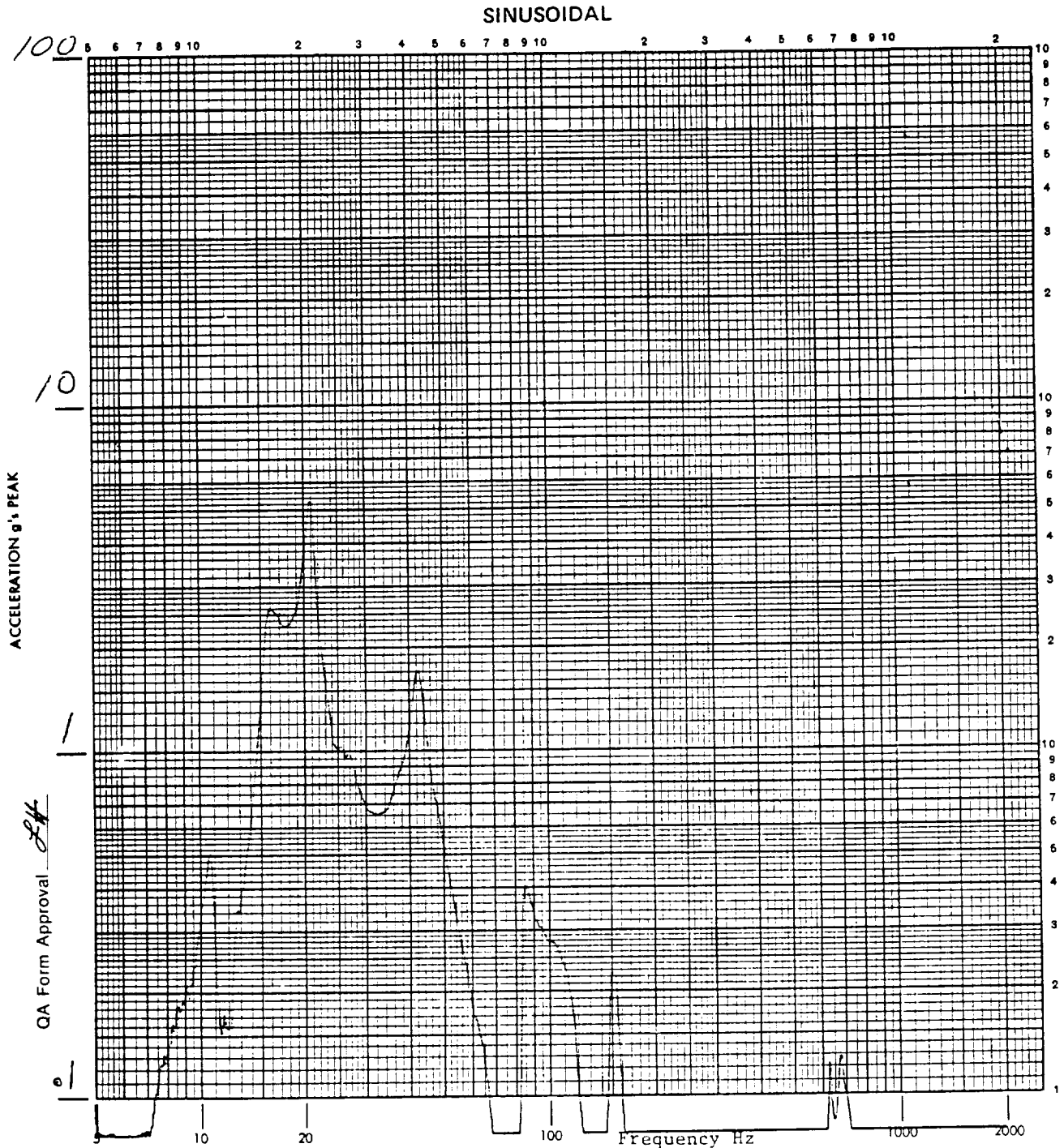
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CUSTOMER MTI Job No. 55976 Date 8-6-89
Specimen UNIT # 1 Axis of Test Long
Accel. No. 2 LONG Control (4th) Response (4) Full Scale 100
Operator mch Engineer C Chen AMB

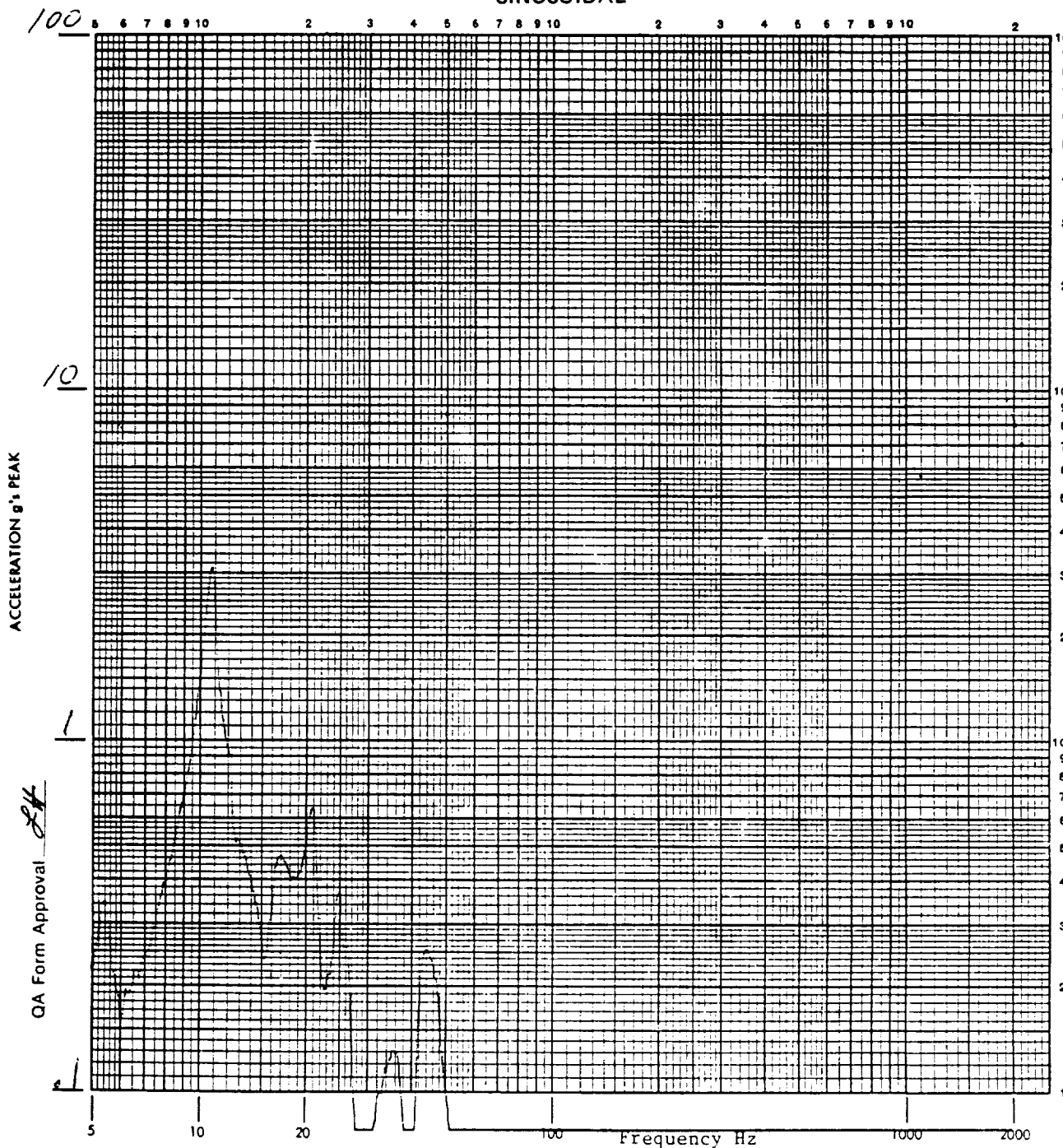


CUSTOMER MTI Job No. 53976 Date 3-6-89
Specimen UNIT 1 Axis of Test LONG
Accel. No. 3 Control () Response (X) Full Scale 100 g
Operator MO- Engineer CCB AMB.



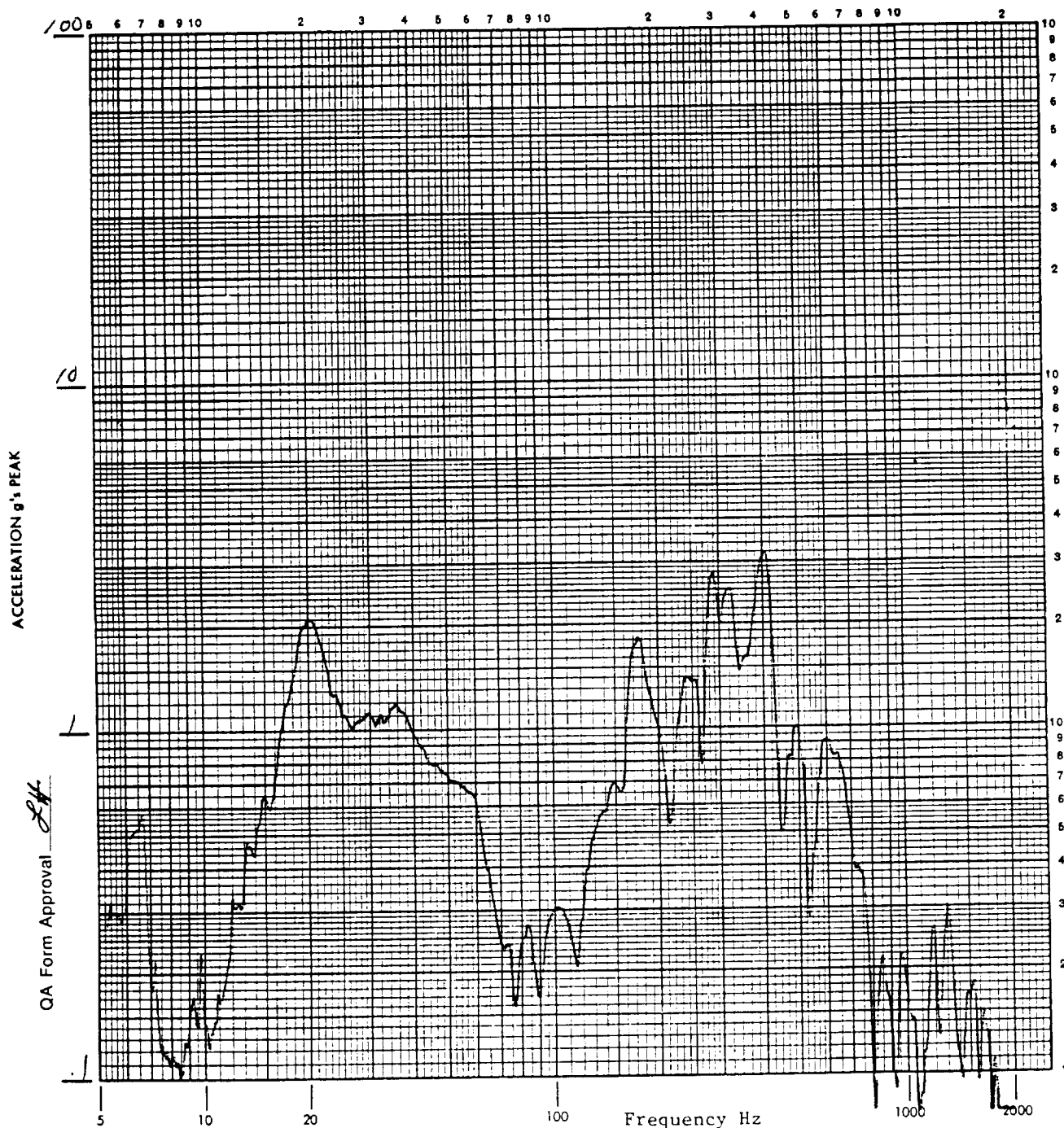
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Specimen UNIT #1 Axis of Test LONG
Accel. No. 4 Control () Response (☒) Full Scale 100
Operator MO Engineer C. Ch AMB

SINUSOIDAL



CUSTOMER MORTON TH10KOL Job No. 53976 Date 3-31-89
Specimen T. M U. Axis of Test TANG
Accel. No. 2 Control () Response (X)
Operator NISPORIC Engineer CCH Full Scale 100 9

SINUSOIDAL



CUSTOMER MORTON THIOKOL

Job No. 53976

Date 3-31-88

Specimen T.M.U.

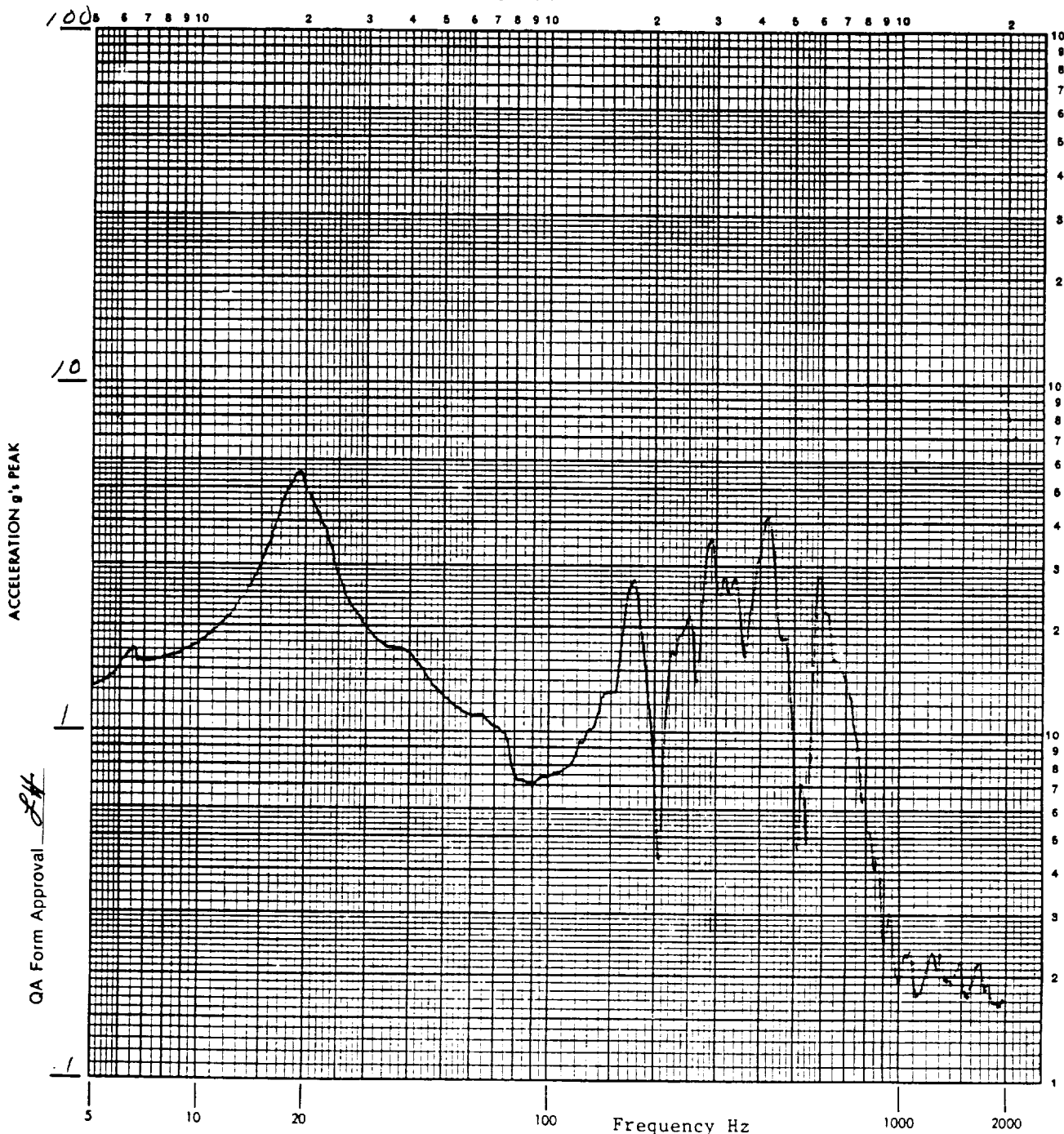
Axis of Test TANG

Accel. No. 3 Control () Response (X)

Full Scale 100 g

Operator M. J. J. Engineer C. C. J.

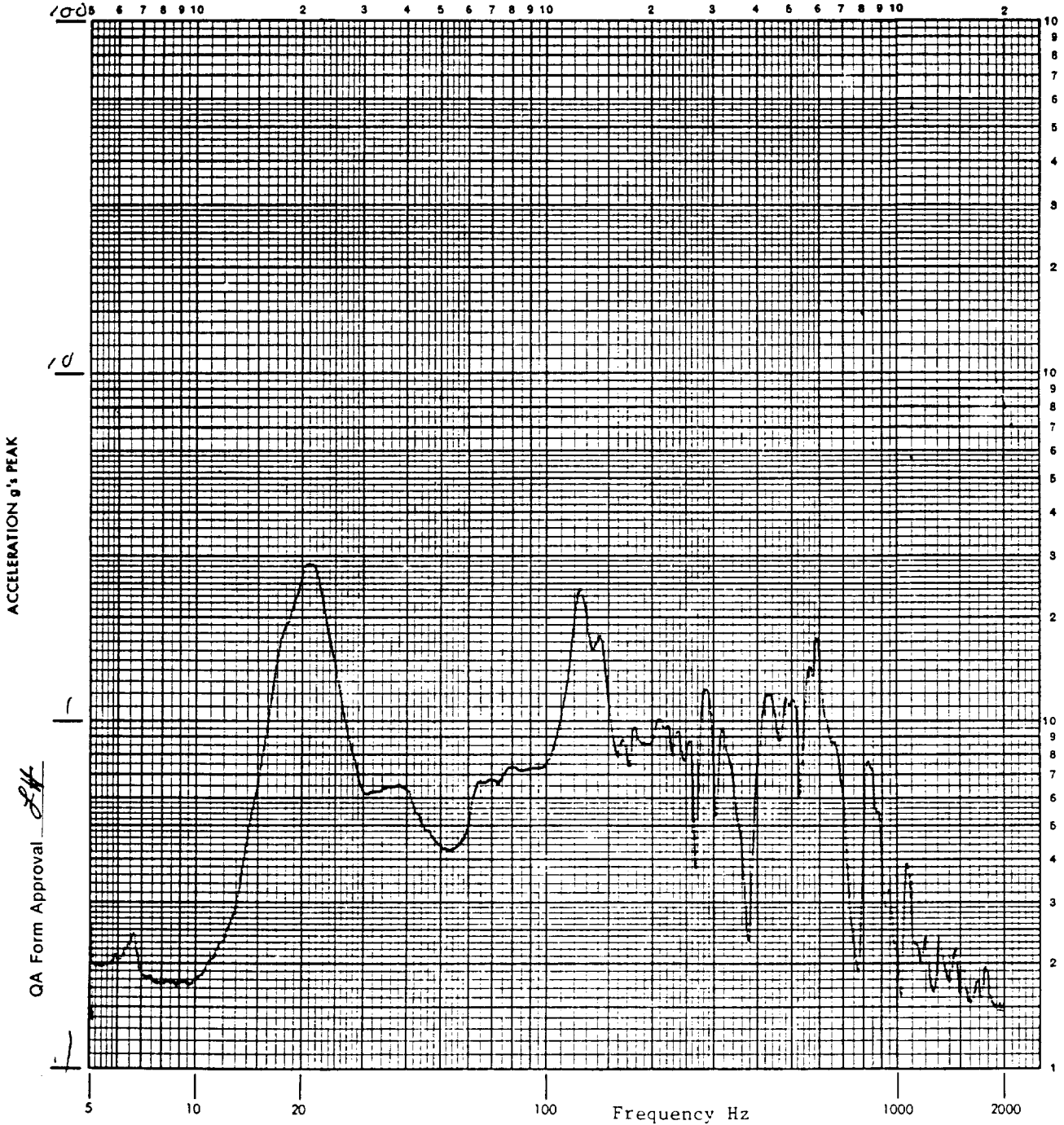
SINUSOIDAL



QA Form Approval 84

CUSTOMER MORTON THICKOL Job No. 53976 Date 3-31-88
Specimen T - M U Axis of Test TANG
Accel. No. 4 Control () Response (X) Full Scale 100 g
Operator [Signature] Engineer [Signature]

SINUSOIDAL



CUSTOMER MORTON THIOKOL

Job No. 53976

Date 3-31-89

Specimen T M U

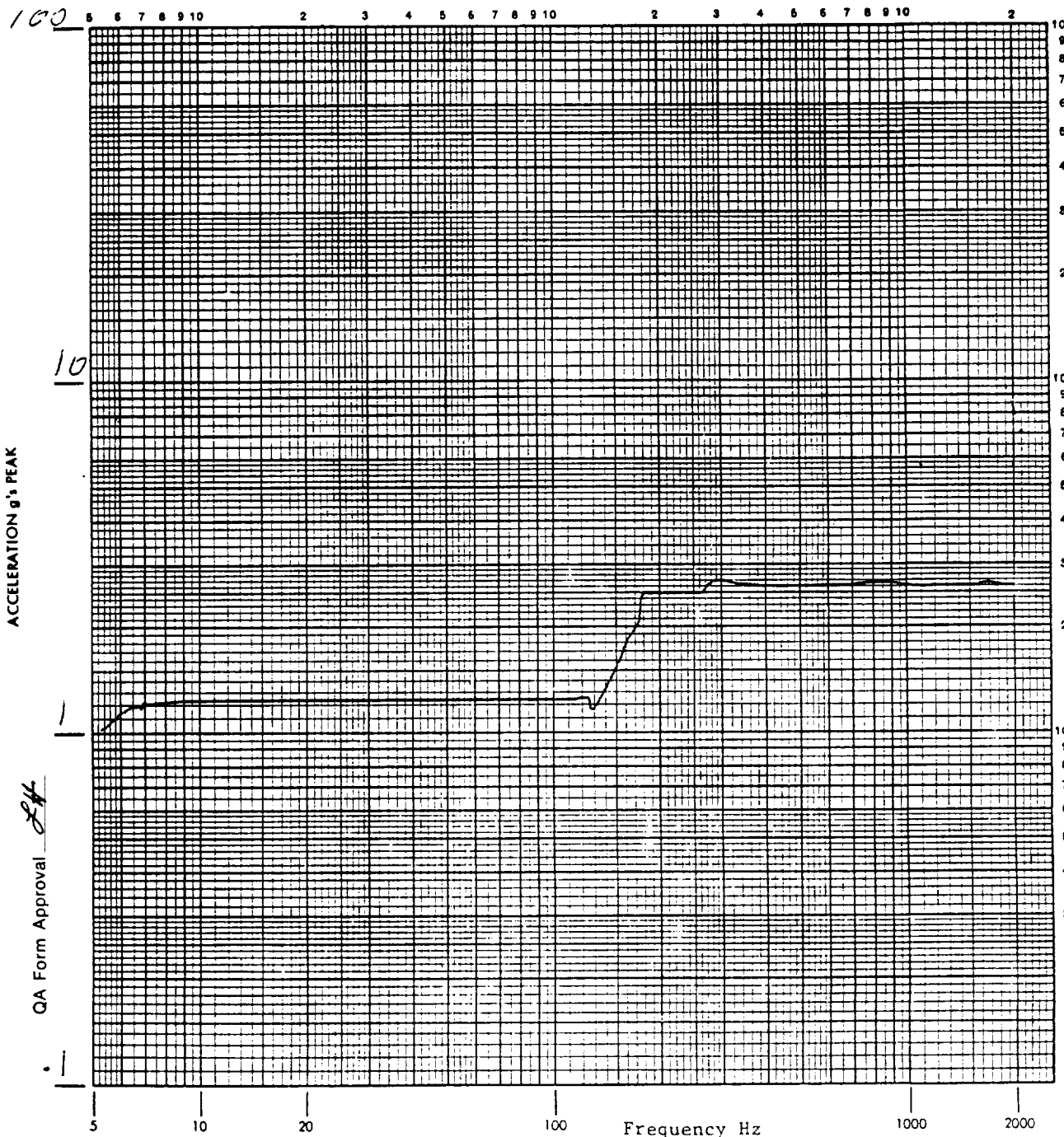
Axis of Test TANG

Accel. No. 1 Control (X) Response ()

Full Scale 100 g

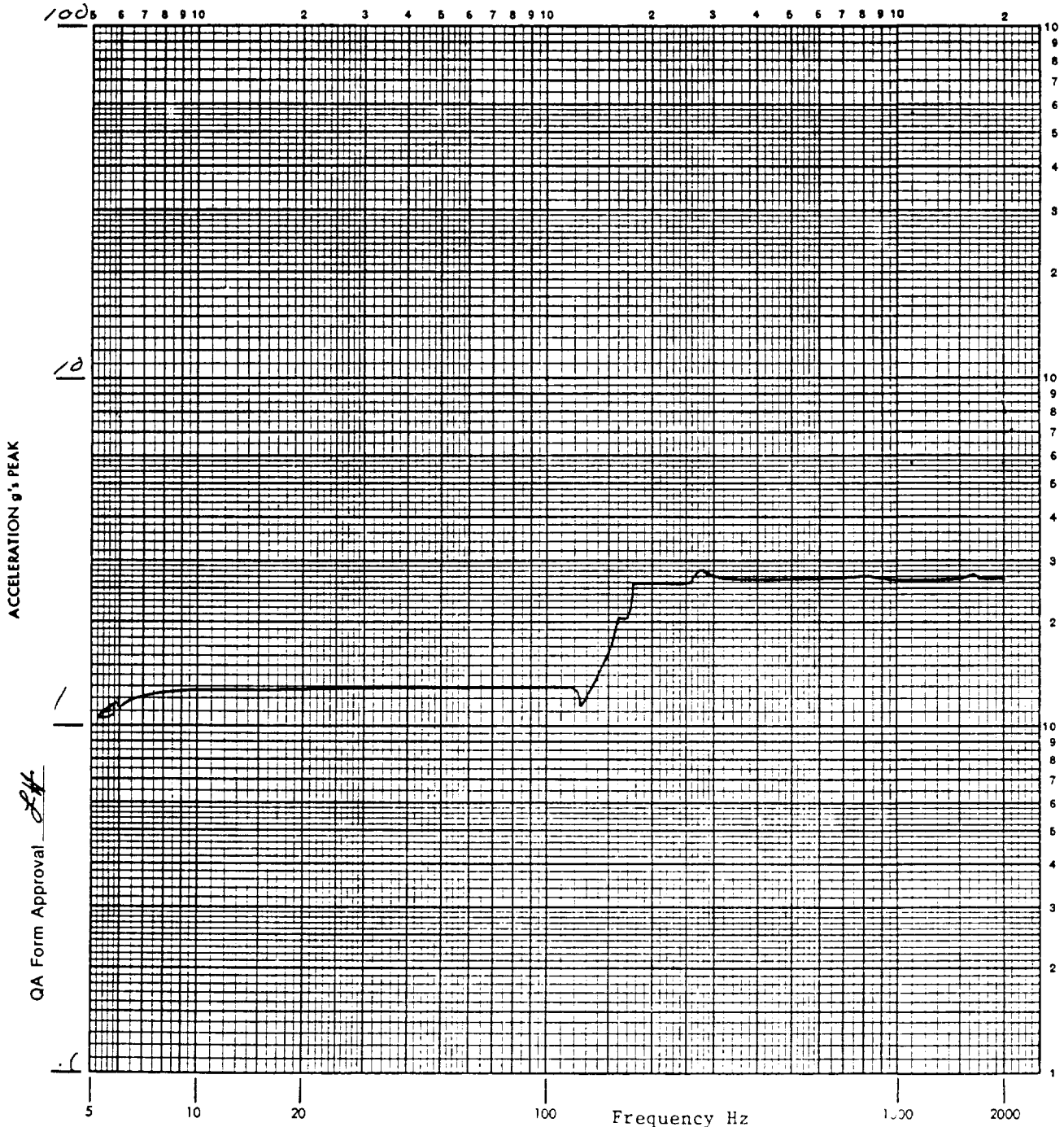
Operator Thyini Engineer CC LEE

SINUSOIDAL



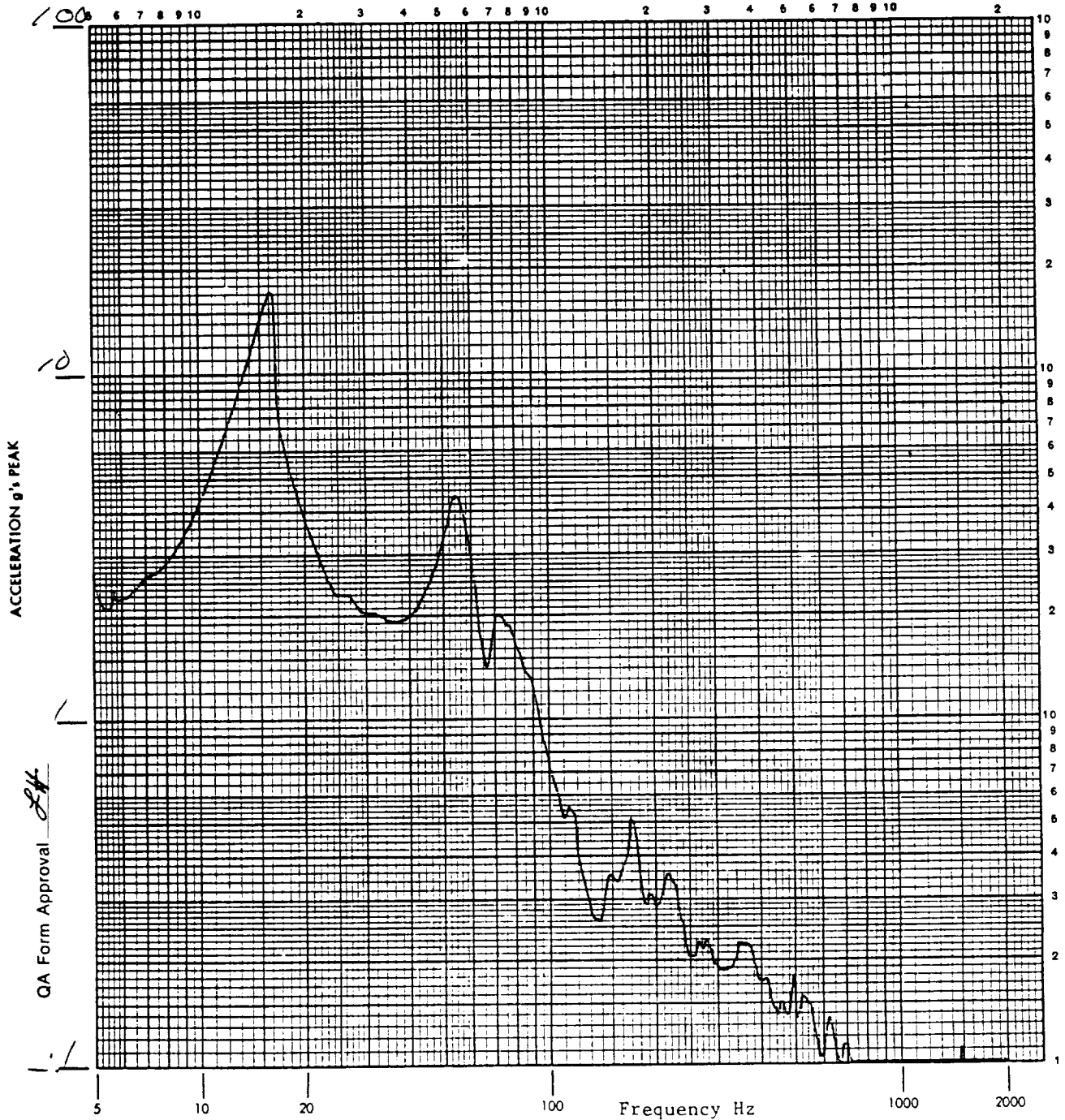
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Specimen T.M.U. UNIT #1 AMB Axis of Test TANG
Accel. No. 1 Control (*) Response () Full Scale 100 g
Operator Mig Engineer CCM

SINUSOIDAL

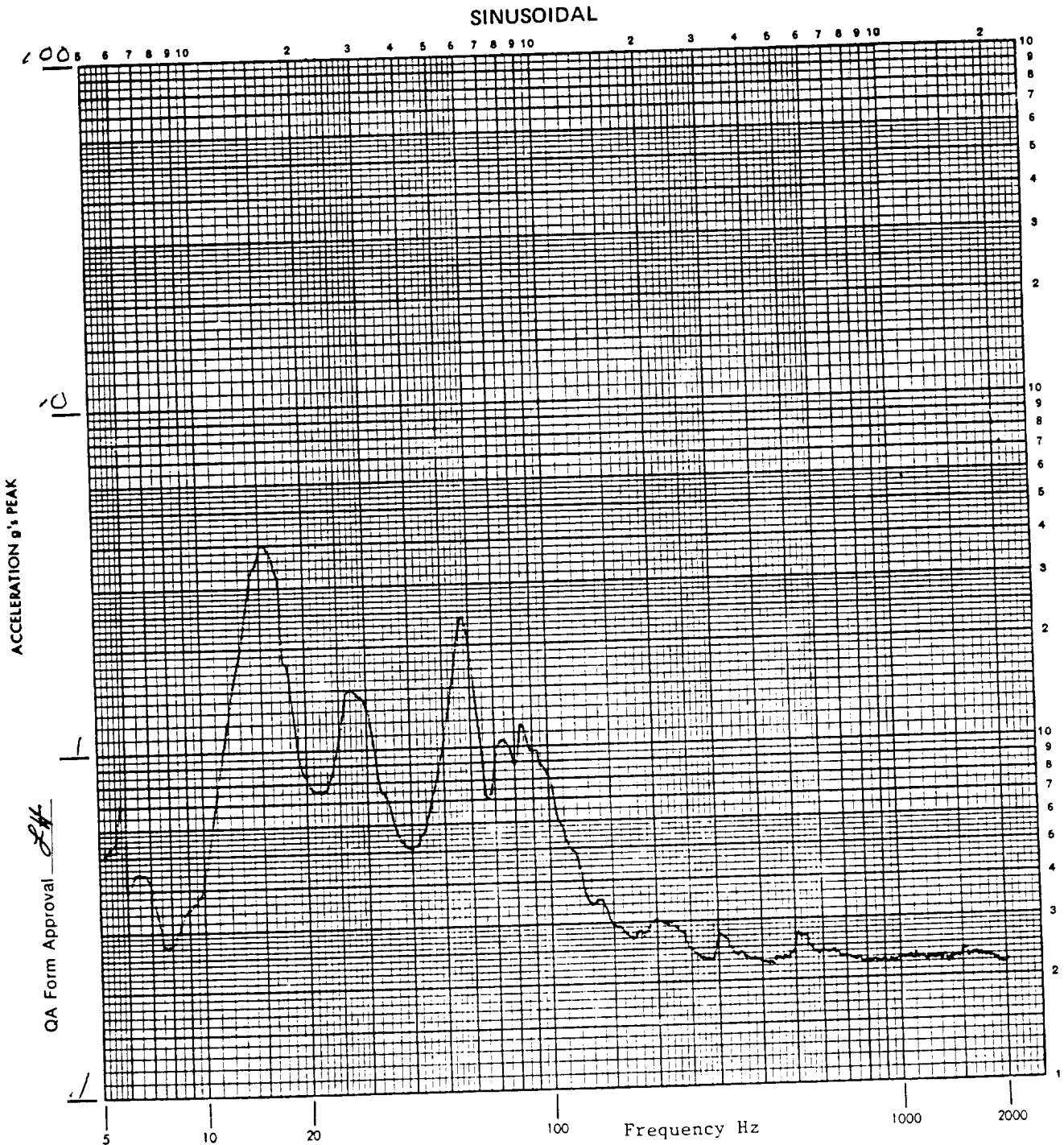


CUSTOMER MTI Job No. 53976 Date 4-3-88
Specimen TMJ UNIT #1 AMB Axis of Test TANG
Accel. No. 3 Control () Response (X)
Operator Ng Engineer CC Full Scale 100 g

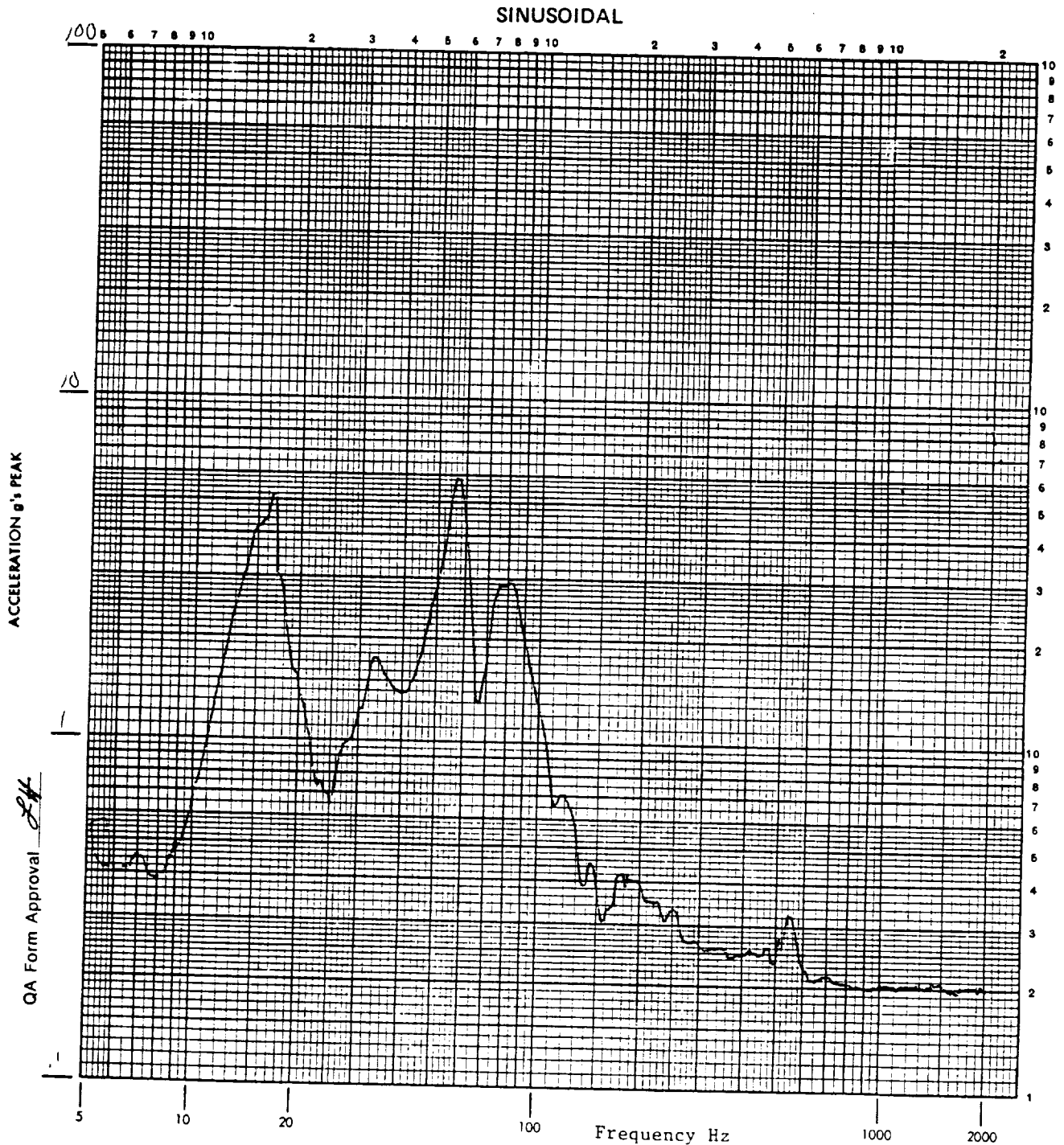
SINUSOIDAL



CUSTOMER MTI Job No. 53976 Date 4-3-89
Specimen TMU Axis of Test TANG
Accel. No. 2 Control () Response (☒) Full Scale 100
Operator Thyrie Engineer CCM

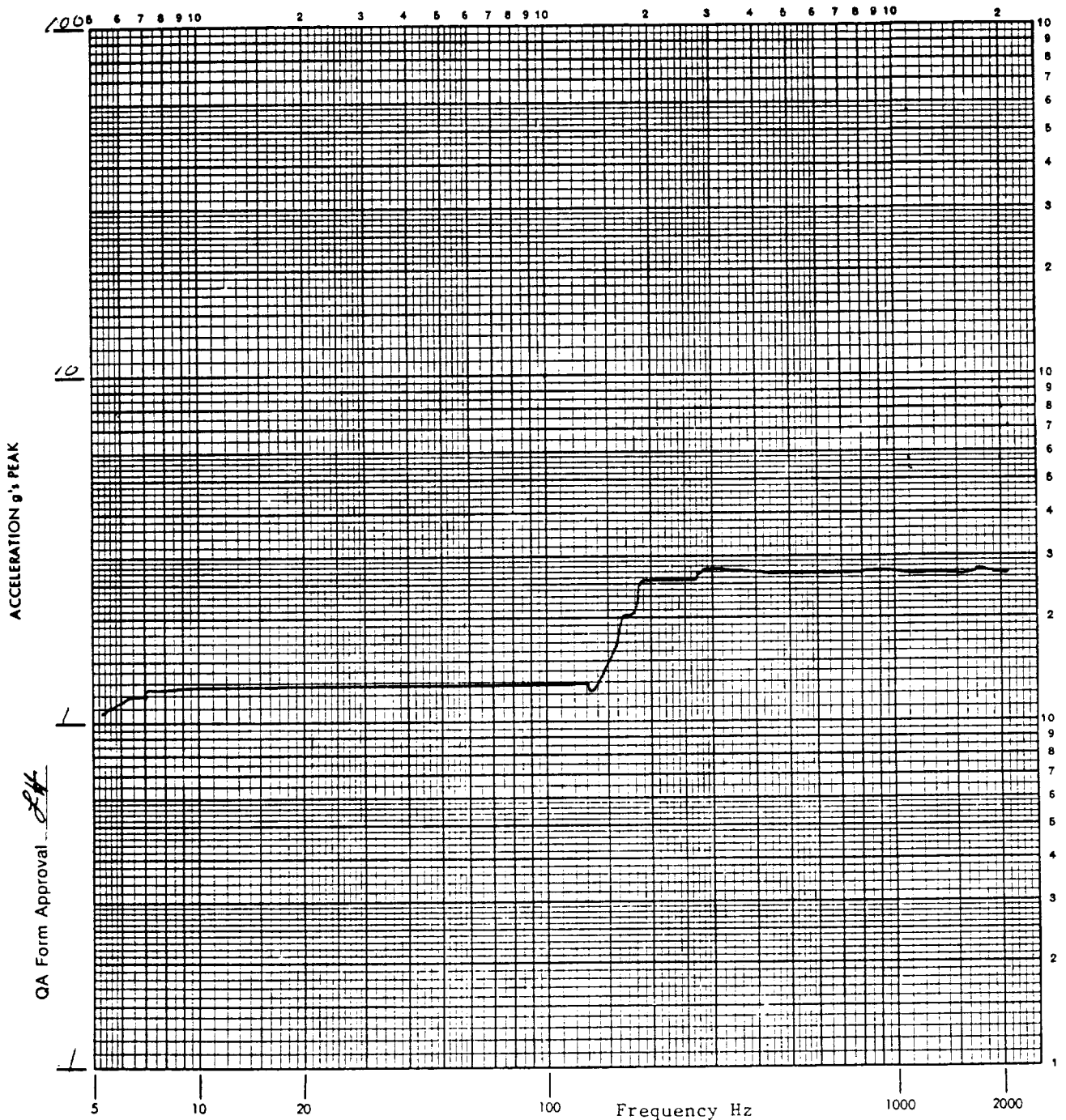


CUSTOMER MTI Job No. 53976 Date 3-4-3-89
Specimen TMU UNIT # 1 AMB Axis of Test TANG
Accel. No. 4 (VERT) Control () Response (X)
Operator M. Higin Engineer C. H. Full Scale 100 g



CUSTOMER MTI Job No. 53976 Date 4-4-89
Specimen T M U UNIT # 1 +163°F Axis of Test TANG
Accel. No. 1 Control (X) Response () Full Scale 100 g
Operator [Signature] Engineer [Signature]

SINUSOIDAL



QA Form Approval [Signature]

CUSTOMER MTI

Job No. 53976

Date 4-4-89

Specimen T MU

Axis of Test TANG

Accel. No. 2

Control ()

Response (*)

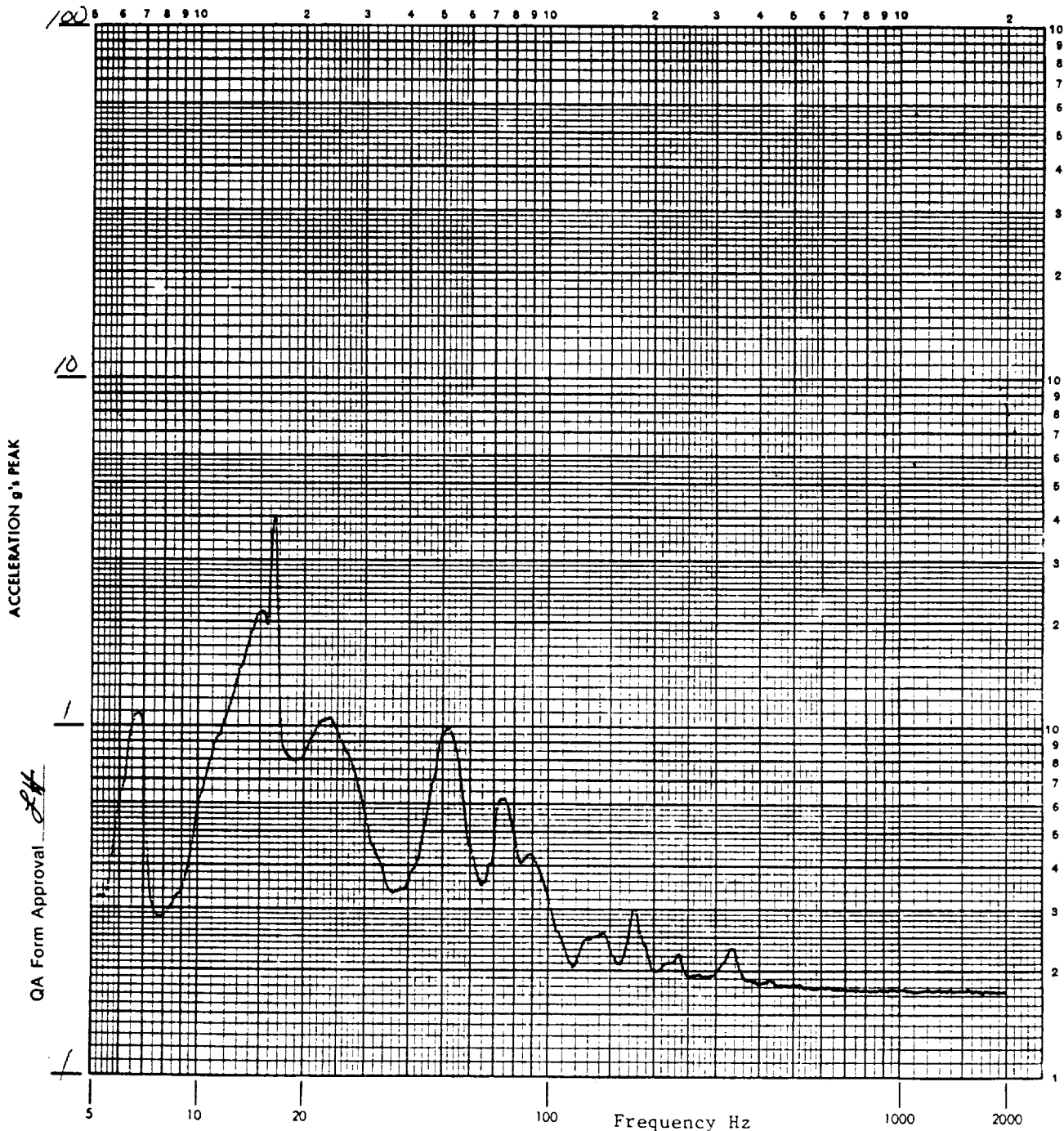
Full Scale 100

g

Operator [Signature]

Engineer [Signature]

SINUSOIDAL



WYLE

LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

Report No. 53976

Page No. 37

CUSTOMER MT 1Job No. 53976Date 4-4-89Specimen T MU

UNIT #1 +163°F

Axis of Test TANGAccel. No. 3

Control ()

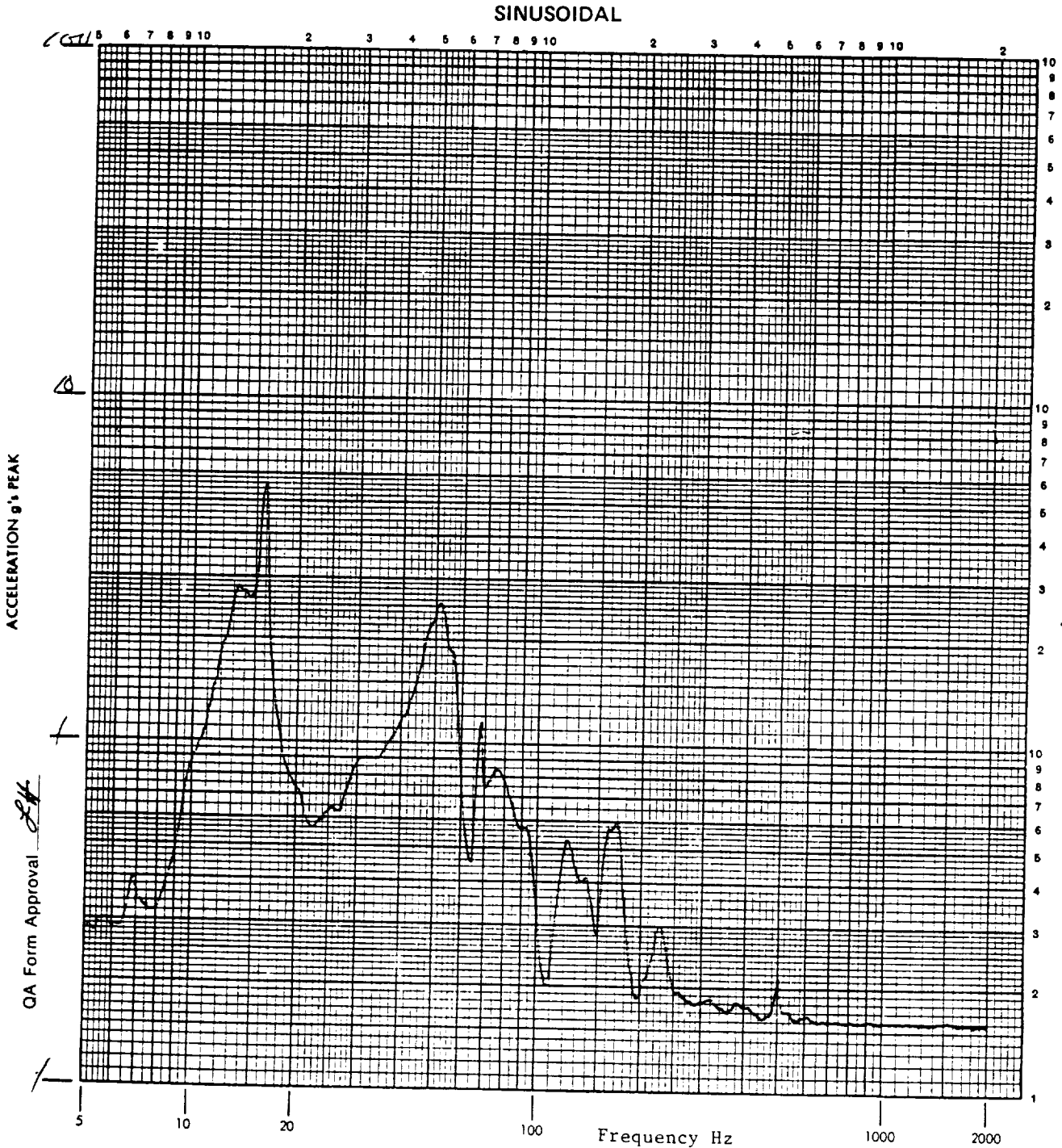
Response (X)

Full Scale 100 gOperator [Signature]Engineer [Signature]

SINUSOIDAL

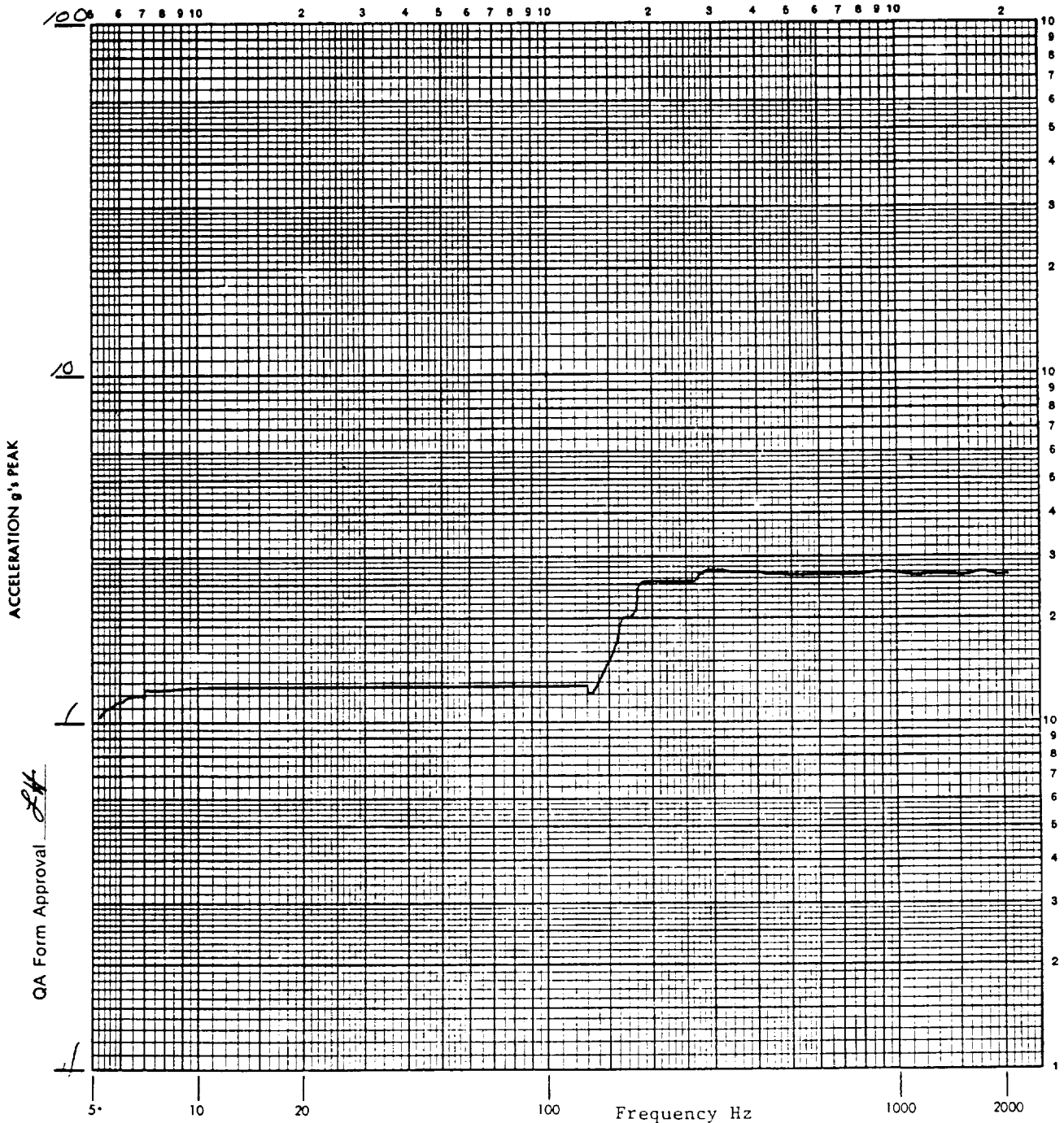


CUSTOMER MTI Job No. 53976 Date 4-4-89
Specimen TMU VERT Axis of Test TANG
Accel. No. 4 Control () Response (*)
Operator [Signature] Engineer [Signature] Full Scale 100 g



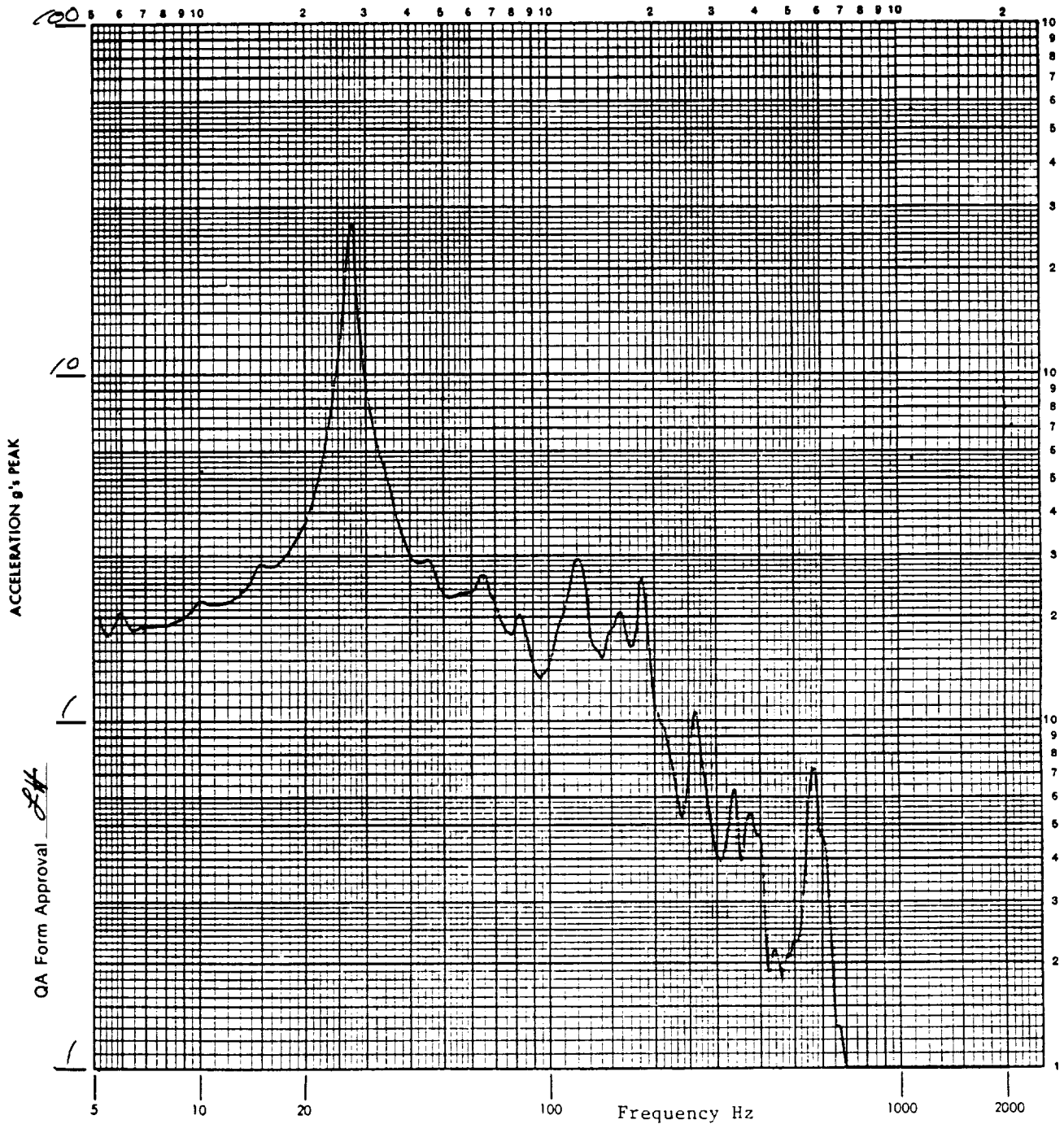
CUSTOMER MT 1 Job No. 53926 Date 4-4-81
Specimen T.M.U. Axis of Test TANG
Accel. No. 1 Control (*) Response () Full Scale 100 g
Operator [Signature] Engineer CCH

SINUSOIDAL



CUSTOMER MT 1 Job No. 53976 Date 4-4-89
Specimen T.MU Axis of Test TANG
Accel. No. 3 Control () Response (~~X~~) Full Scale 100 g
Operator [Signature] Engineer CCH

SINUSOIDAL



CUSTOMER MTI

Job No. 53976

Date 4-4-89

Specimen TMU

UNIT # 2

Axis of Test TANC

Accel. No. 2

Control ()

Response (X)

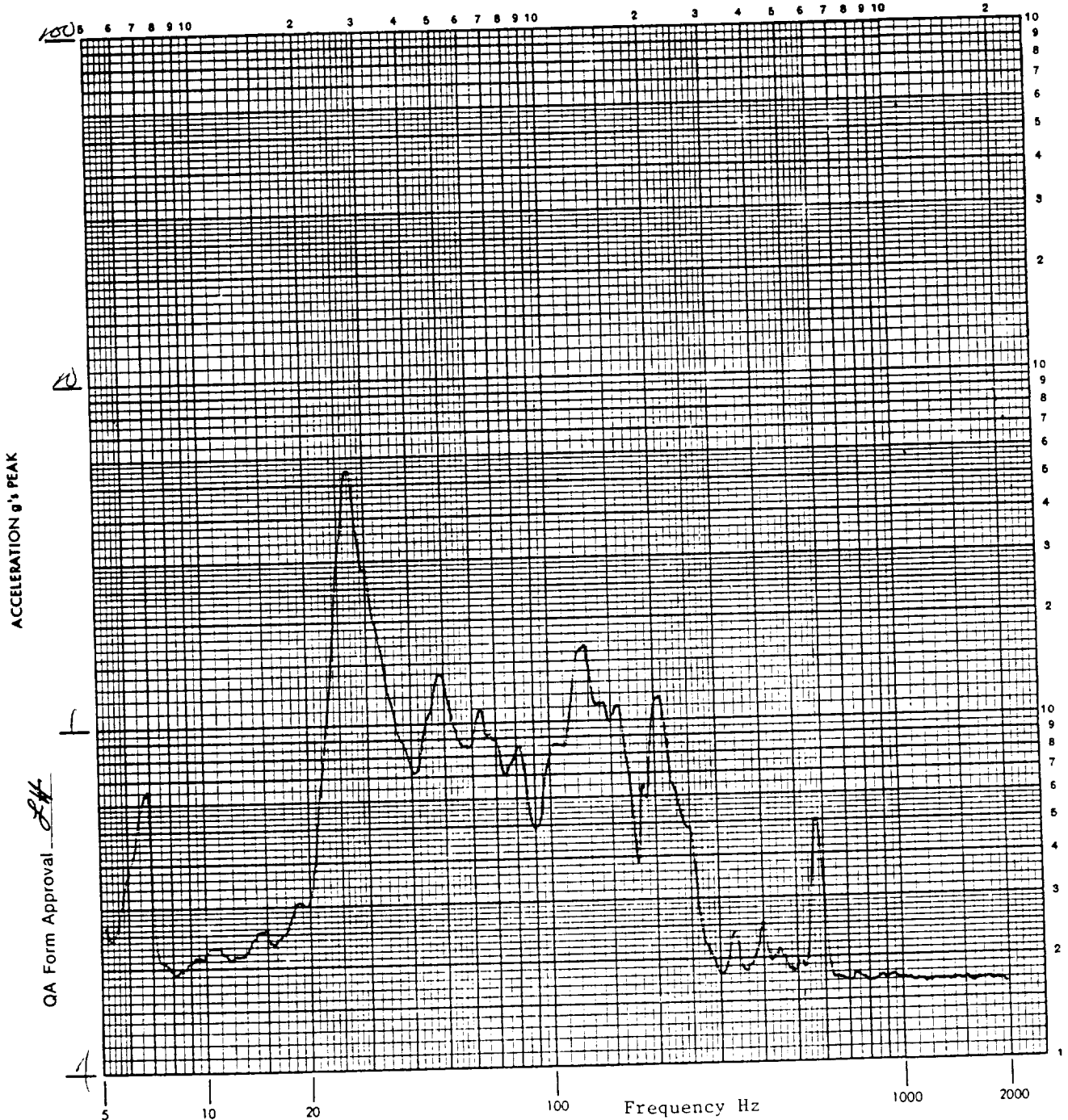
Full Scale 100 g

Operator Thi

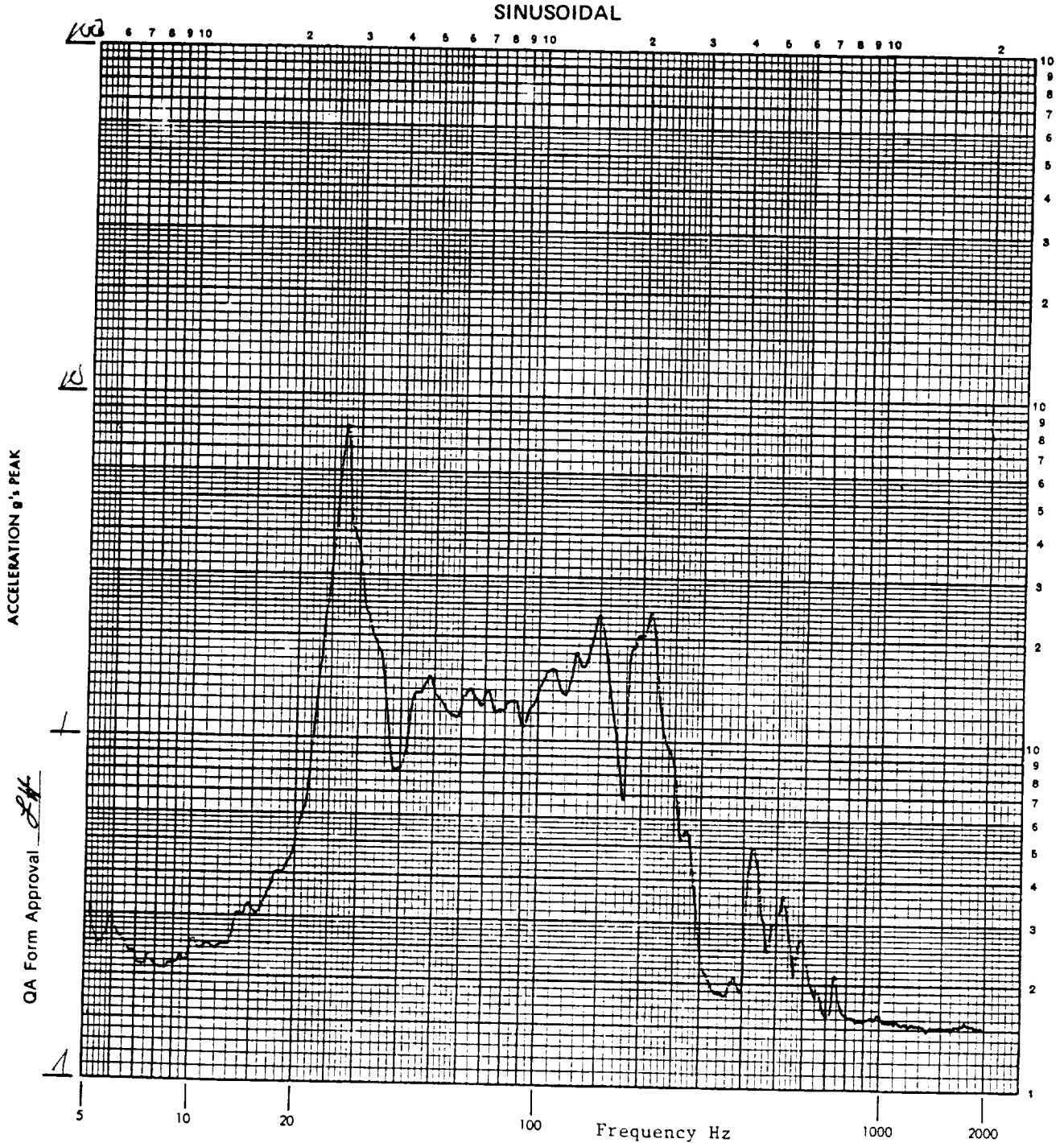
Engineer CCH

AMB $70^{\circ}F \pm 10^{\circ}$

SINUSOIDAL



CUSTOMER MTI Job No. 53976 Date 4-4-88
Specimen T.M.U. Axis of Test TANG
Accel. No. 4 Control () Response (X)
Operator [Signature] Engineer C. C. [Signature] Full Scale 100 g



DATA SHEET

TEST TITLE SHOCK

CUSTOMER M.T.I. Job No. 53976
Specimen T.M.U. Date Started 3-25-85
Part No. PROTYPE Serial No. UNITS II Date Comp. 4-5-89
Spec. MTITP CTP-0097 Par. 8 Photo YES Amb. Temp. 70°F ± 10°

THE TEST SPECIMENS WERE MOUNTED TO SHOCK MOUNTS PROVIDED BY CUSTOMER THEN ATTACHED TO A VIBRATION FIXTURE (SLIP PLATE) WHICH IN TURN WAS SECURED TO AN ELECTRO DYNAMIC EXCITER TEMPERATURE CONDITIONED FOR A MINIMUM OF FOUR HOURS AND SUBJECTED TO THE FOLLOWING TEST LEVELS

SHOCK LEVELS :

20-160 HZ +6 DB/OCT
160-340 HZ 10 G PEAK
340-400 HZ -6 DB/OCT

TEMPERATURE CRITERIA

TOL

- 20° F ± 10°
AMBIENT + 70° F ± 10°
+ 163° F ± 10°

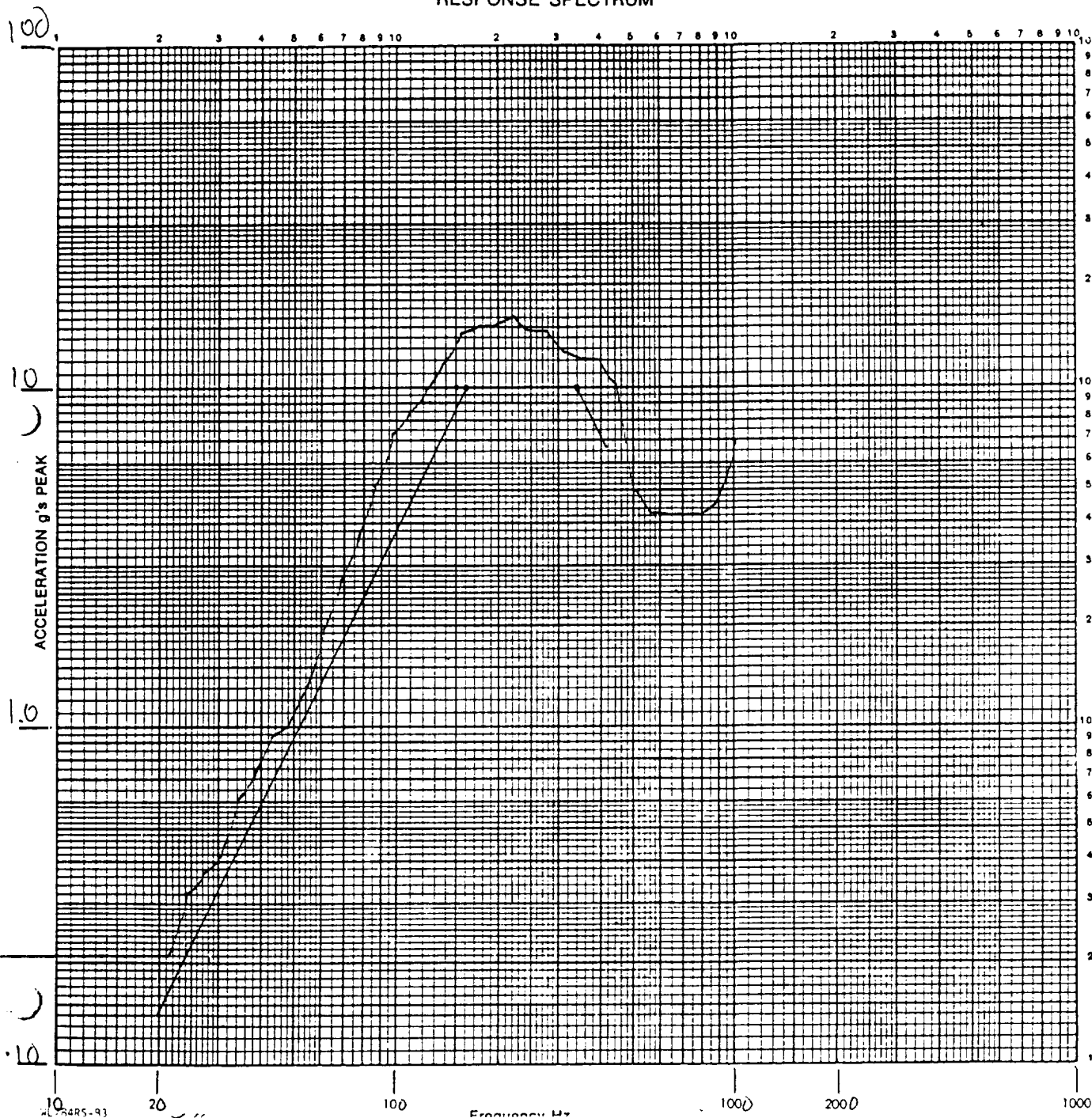
DATA SHEET

TEST TITLE TRANSPORTATION SHOCK DATE 3-6-89
Customer MTI Job No. 53976
Specimen T.M.U. Technician MOL
Part No. _____ Serial No. UNIT 1-2 Engineer C.C. LEE

Date	Time	Axis	Test	Comments
1989	NOTED	NOTED	TEMPERATURE	
3-3	1450	LONG	-20°F	SHOCK #1 UNIT #1
	1451			#2
	1452			#3
	1453			#4
	1454			#5
3-3	1612			SHOCK #1 UNIT #2
	1613			#2
	1614			#3
	1615			#4
	1616			#5
3-6	1025		+70 AMBIENT	SHOCK #1 UNIT #2
	1027			#2
	1028			#3
	1029			#4
	1031			#5
3-6	1105			SHOCK #1 UNIT #1
	1107			#2
	1109			#3
	1110			#4
	1112			#5

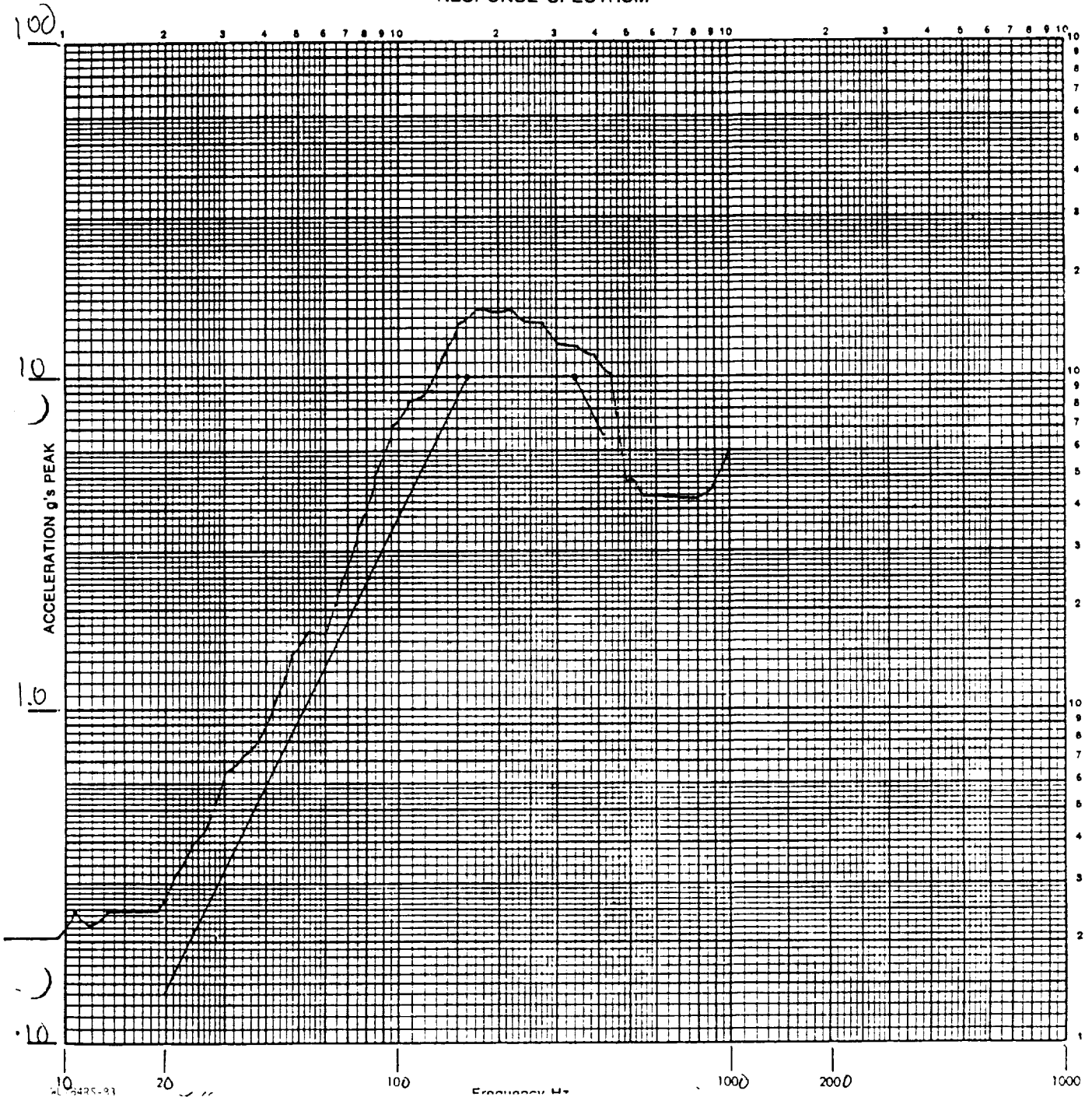
CUSTOMER MTI Job No. 53976 Date 3-3-89
2-25-89
 Specimen TRANSPORTATION UNIT Axis of Test LONG
 Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()
 Full Scale 100 g Damping 5 % Run No. CAL NO. 1
 Operator MOL Engineer C C. L. -20°F

RESPONSE SPECTRUM



CUSTOMER MTI Job No. 53976 Date 3-3 1985
Specimen TRANSPORTATION UNIT Axis of Test LONG.
Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. CAL NO. 2
Operator M. C. Engineer C. C. L. -20°F

RESPONSE SPECTRUM



CUSTOMER MTI

Job No. 53976

Date 3-3-85

Specimen TRANSPORTATION UNIT #1

Axis of Test LONG

Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()

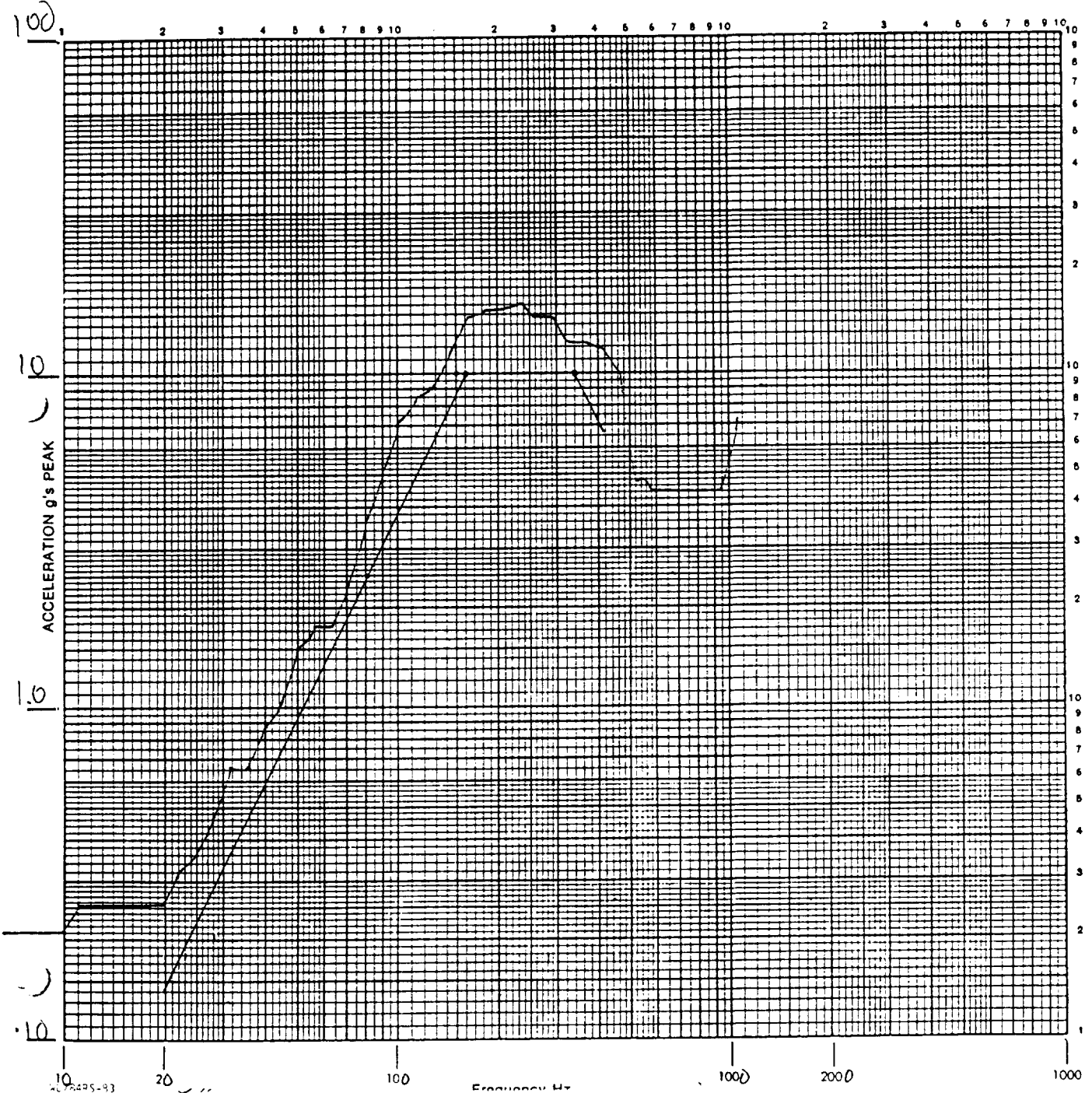
Full Scale 100 g Damping 5 %

Run No. #1

Operator MCE Engineer CCH

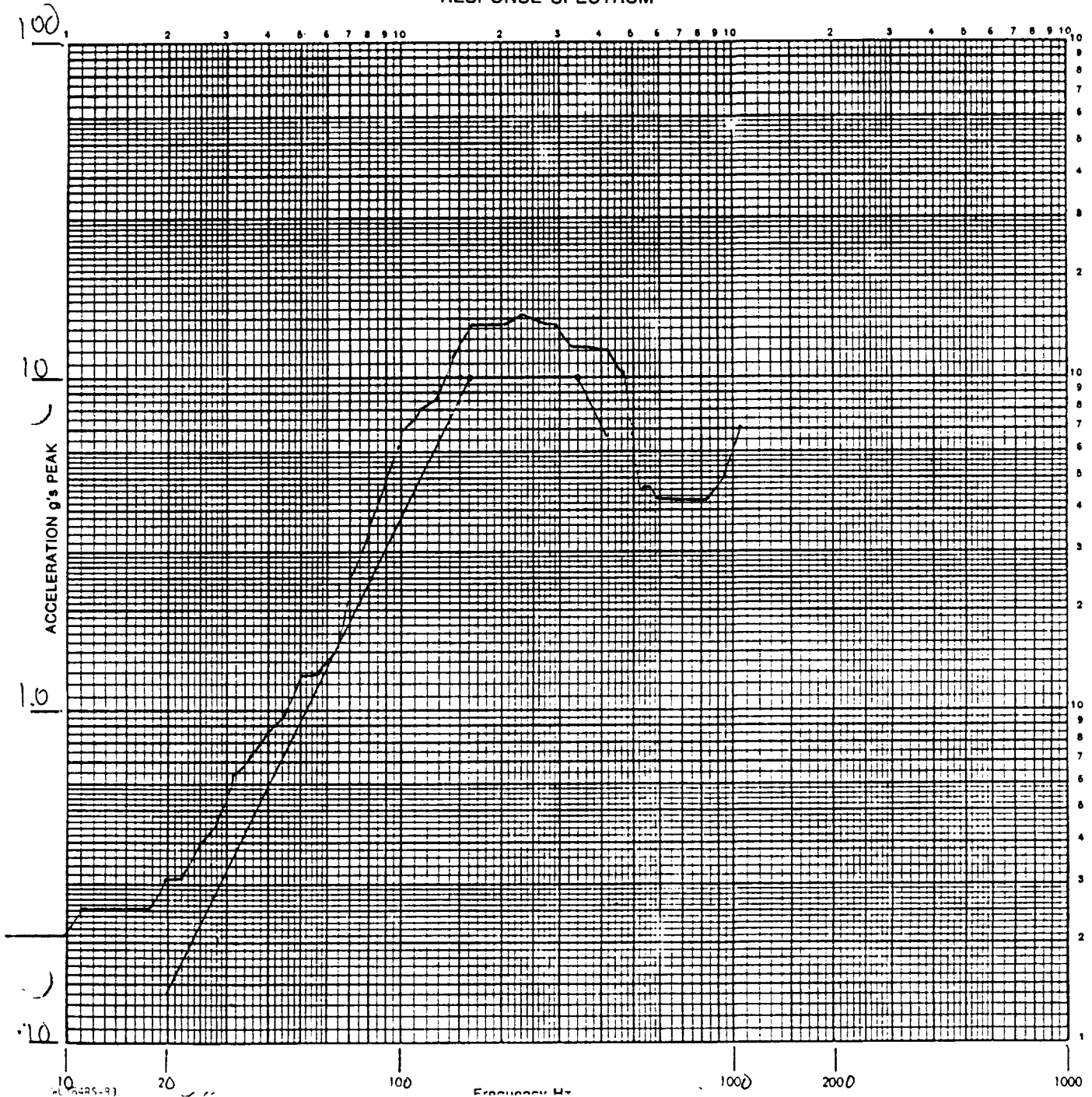
-20°F

RESPONSE SPECTRUM



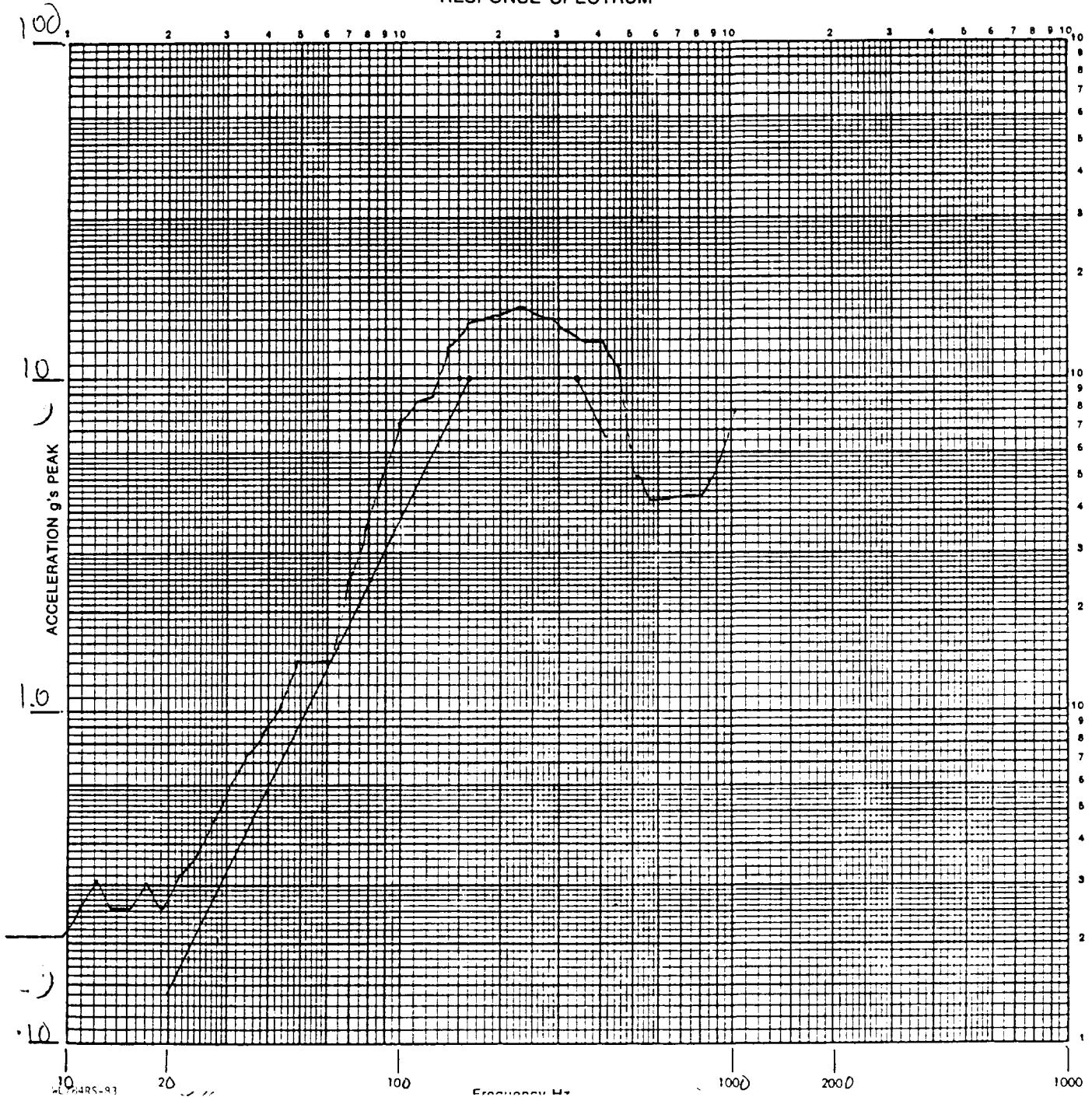
CUSTOMER MTI Job No. 53976 Date 3-3 1985
Specimen TRANSPORTATION UNIT #1 Axis of Test LONG
Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. #2
Operator MC Engineer CSH -20°F

RESPONSE SPECTRUM



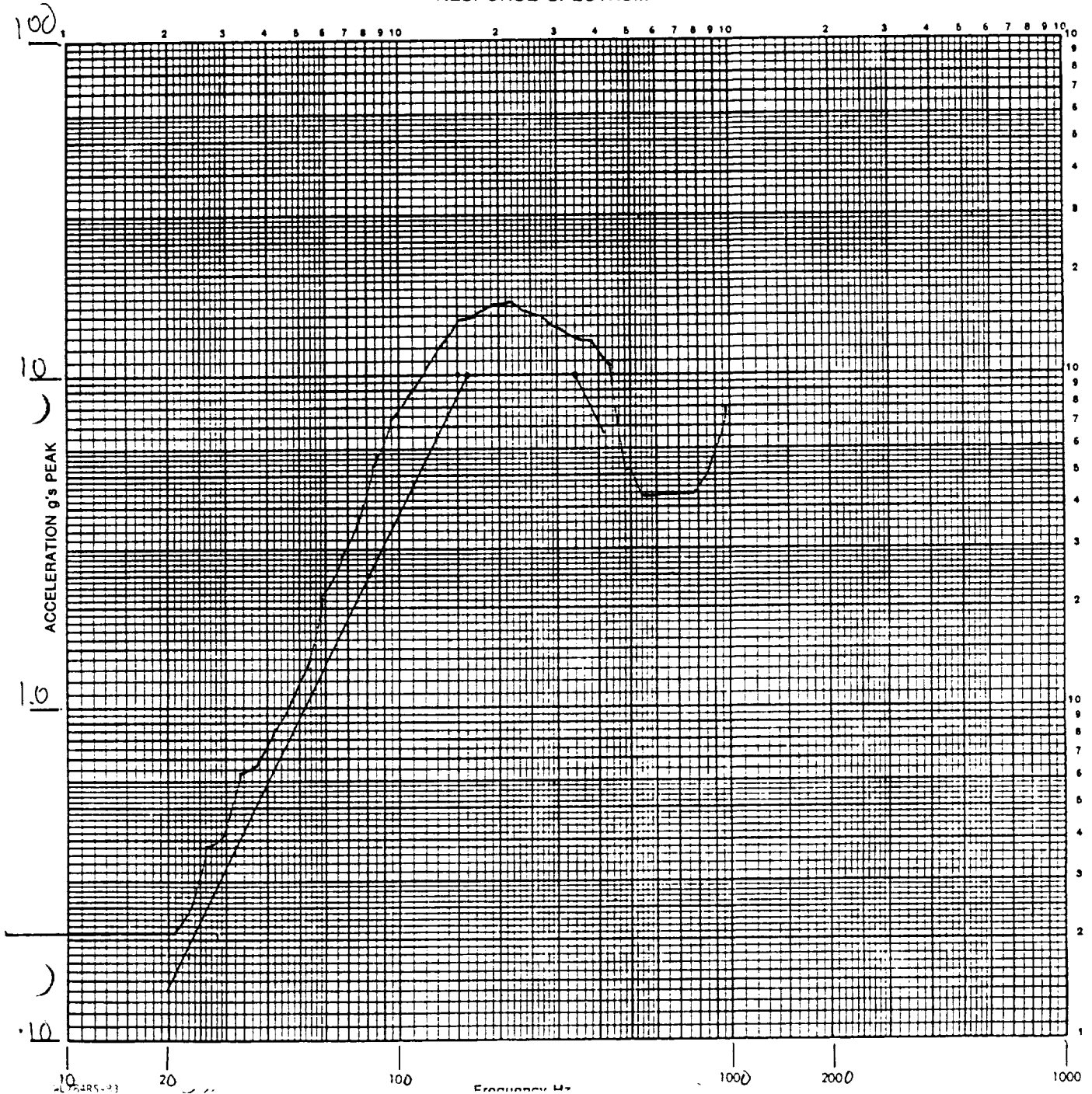
CUSTOMER MTI Job No. 53976 Date 3-3-85
Specimen TRANSPORTATION UNIT #21 Axis of Test LONG
Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. #3
Operator MAC Engineer cc/m
-200R

RESPONSE SPECTRUM



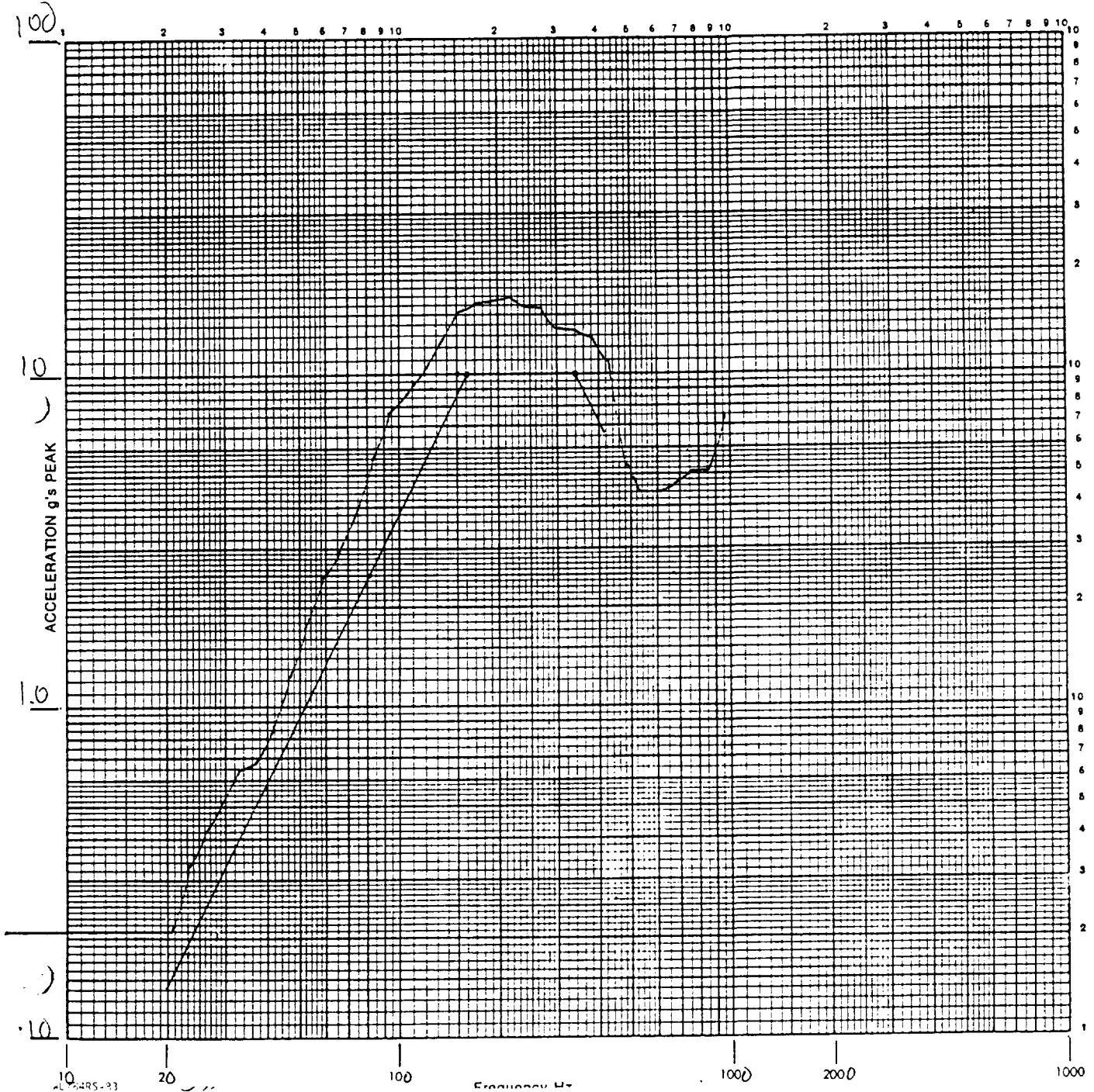
CUSTOMER MTI Job No. 53976 Date 4-25-85
Specimen TRANSPORTATION UNIT #1 Axis of Test LONG
Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. #1
Operator MM Engineer CCH -20°F

RESPONSE SPECTRUM



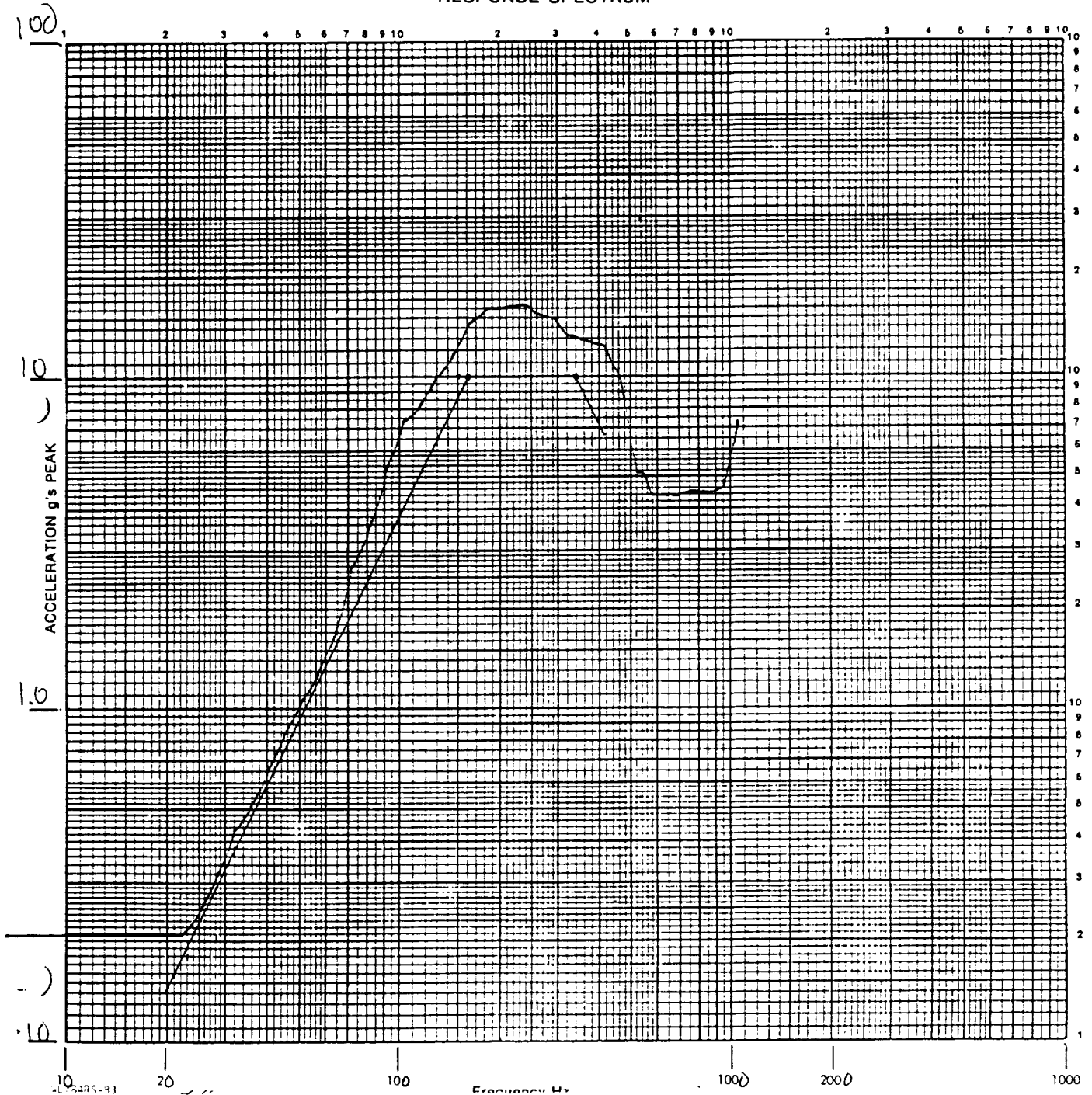
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Specimen TRANSPORTATION UNIT #1 Axis of Test Long
Accel. No. 1 Axis LONG Control (☒) Response (☐) OBE (☐) SSE (☐) DBE (☐)
Full Scale 100 g Damping 5 % Run No. #5
Operator MOH Engineer CCM -20°F

RESPONSE SPECTRUM



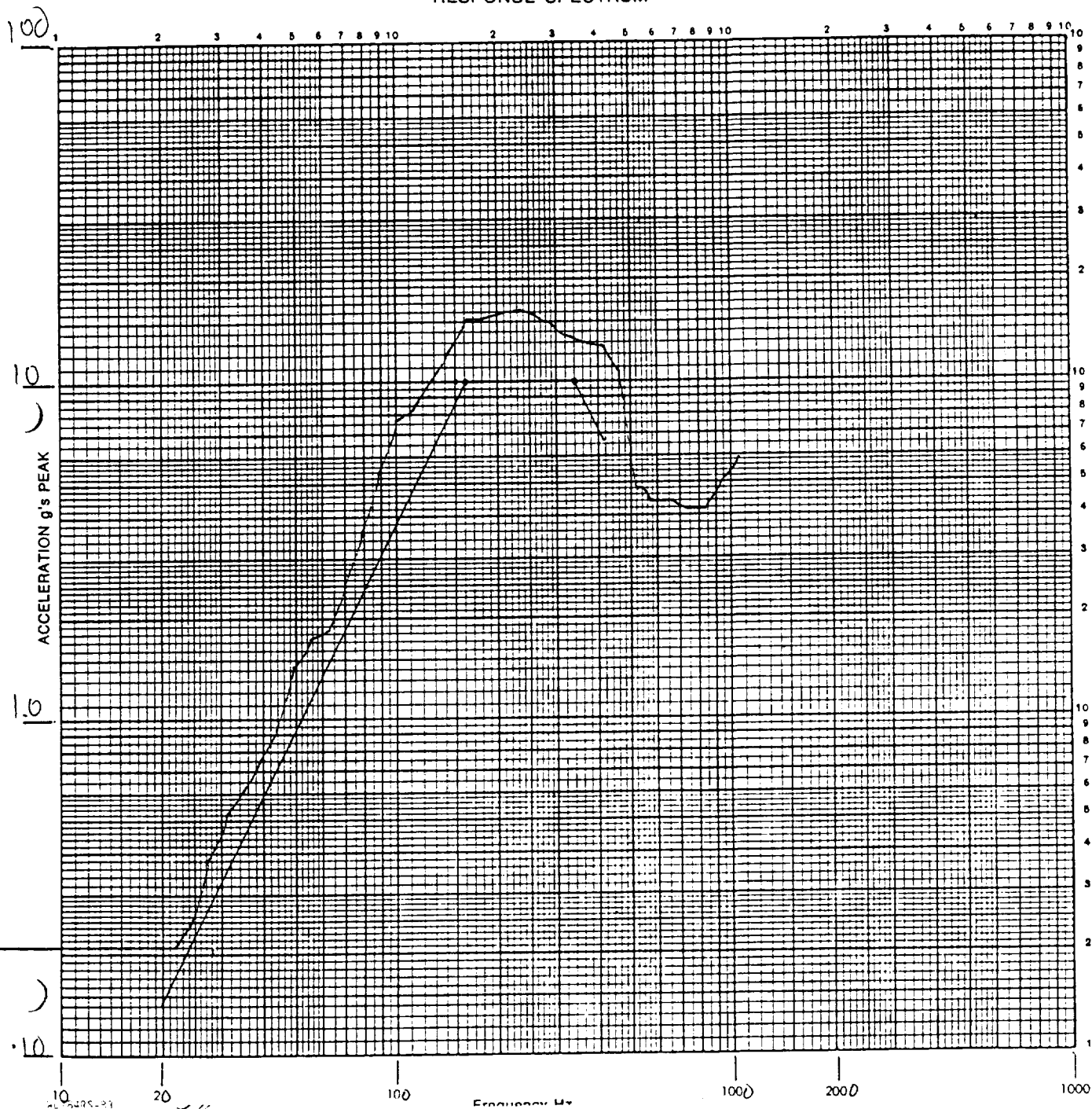
CUSTOMER MTI Job No. 53976 Date CLL3-3 2-25-85
Specimen TRANSPORTATION UNIT #2 Axis of Test Long
Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. #1
Operator Ma Engineer CCM -2002

RESPONSE SPECTRUM



CUSTOMER MTI Job No. 53976 Date 3-3-85
Specimen TRANSPORTATION UNIT #2 Axis of Test Long
Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. #2
Operator MC Engineer CC -20°C

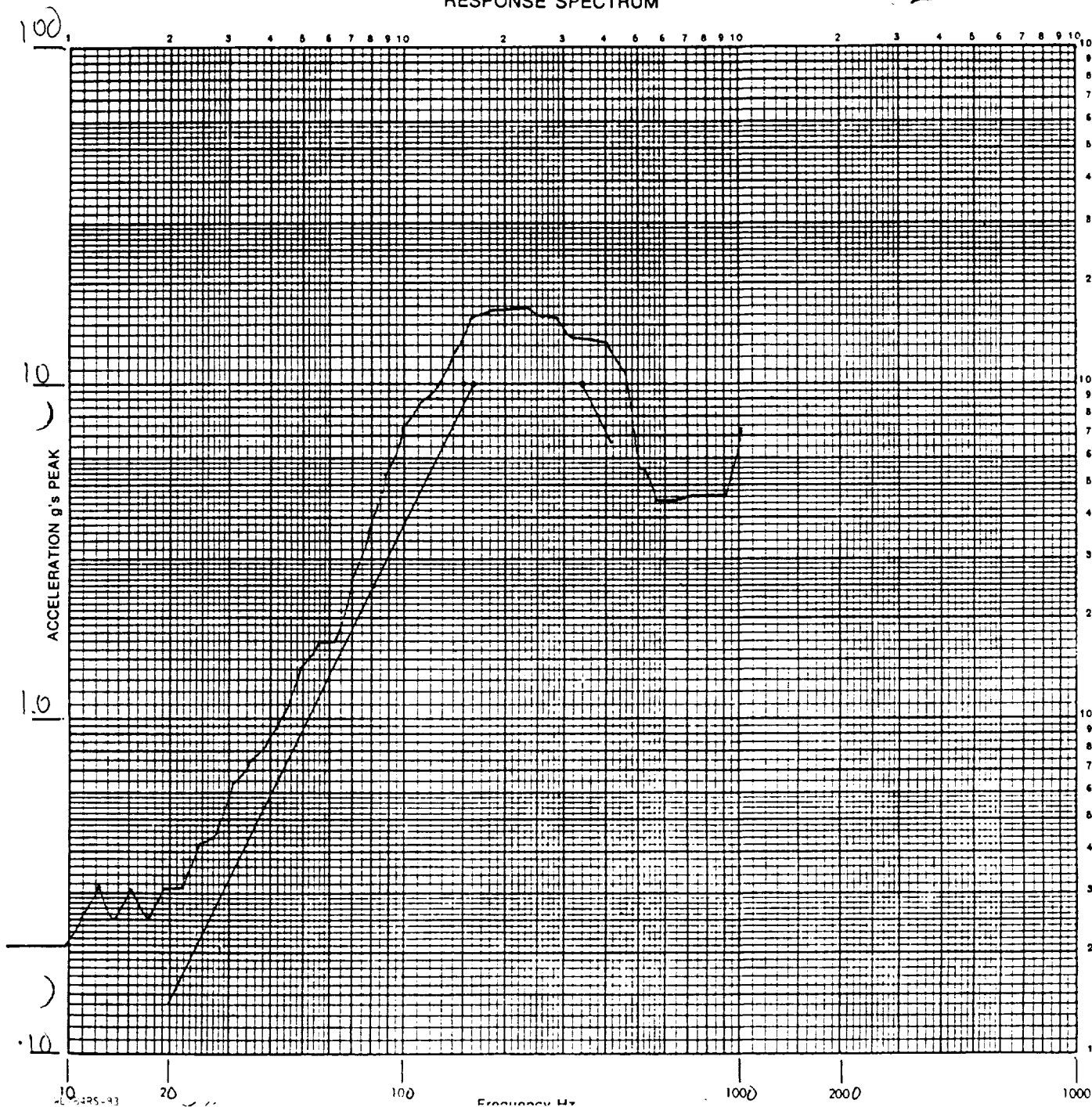
RESPONSE SPECTRUM



CUSTOMER MTI Job No. 53976 Date 6-25-89
Specimen TRANSPORTATION UNIT #2 Axis of Test Long
Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. #3
Operator MC Engineer CCM

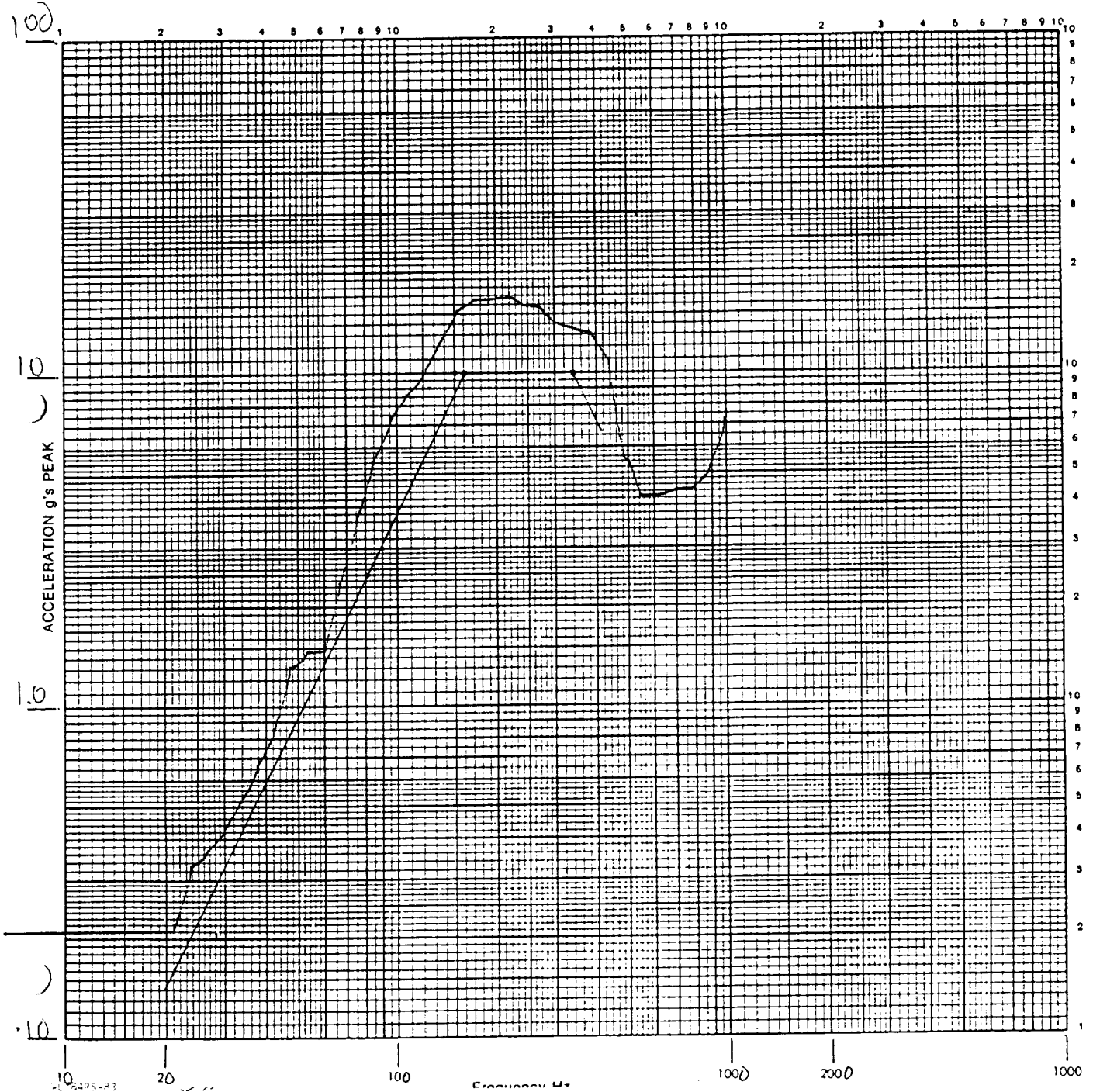
RESPONSE SPECTRUM

-20°F



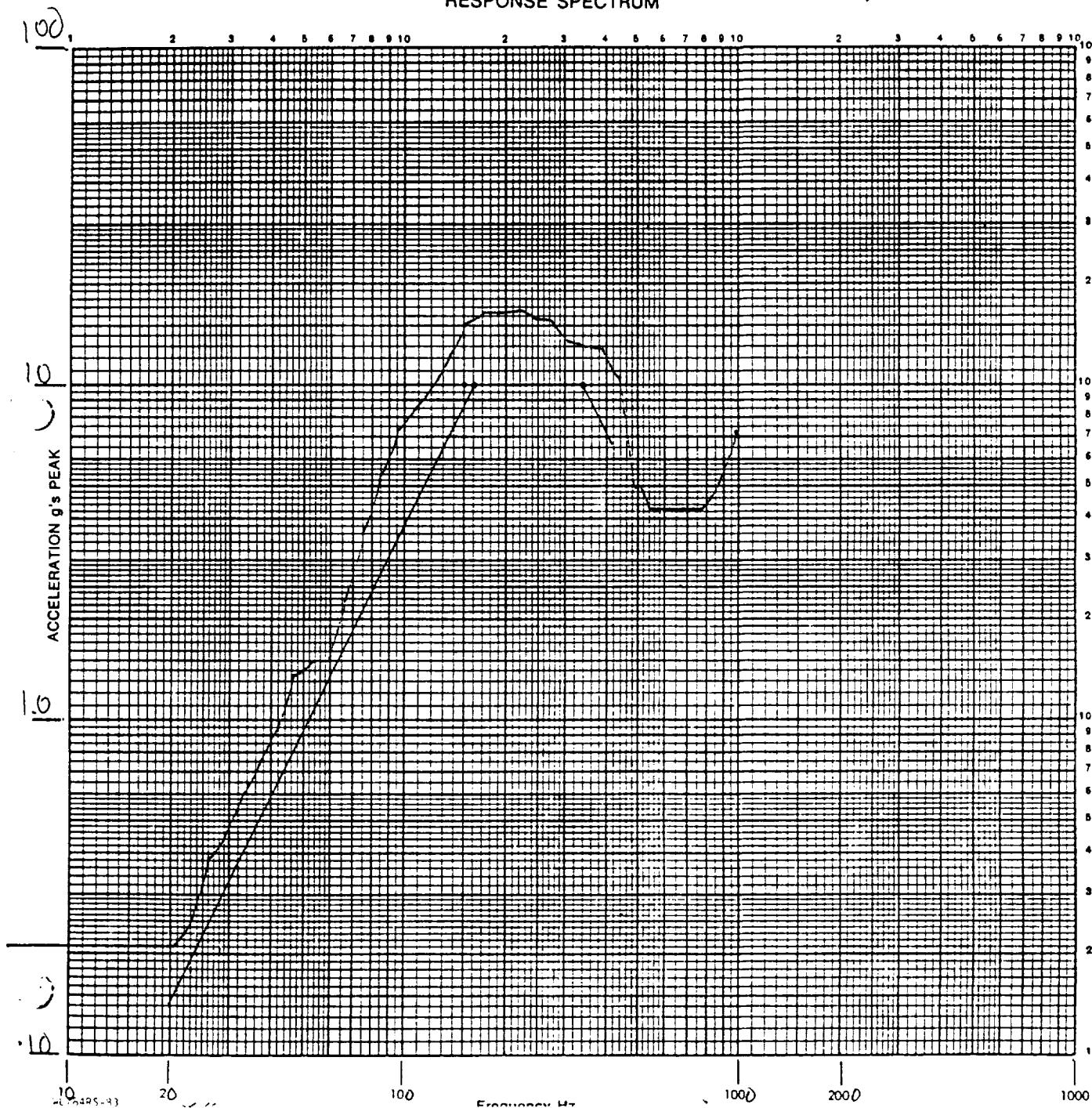
CUSTOMER MTI Job No. 53976 Date 3-3 2-25-89
Specimen TRANSPORTATION UNIT #2 Axis of Test Long
Accel. No. 1 Axis LONG. Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. # 41
Operator ma Engineer CCM -200P

RESPONSE SPECTRUM



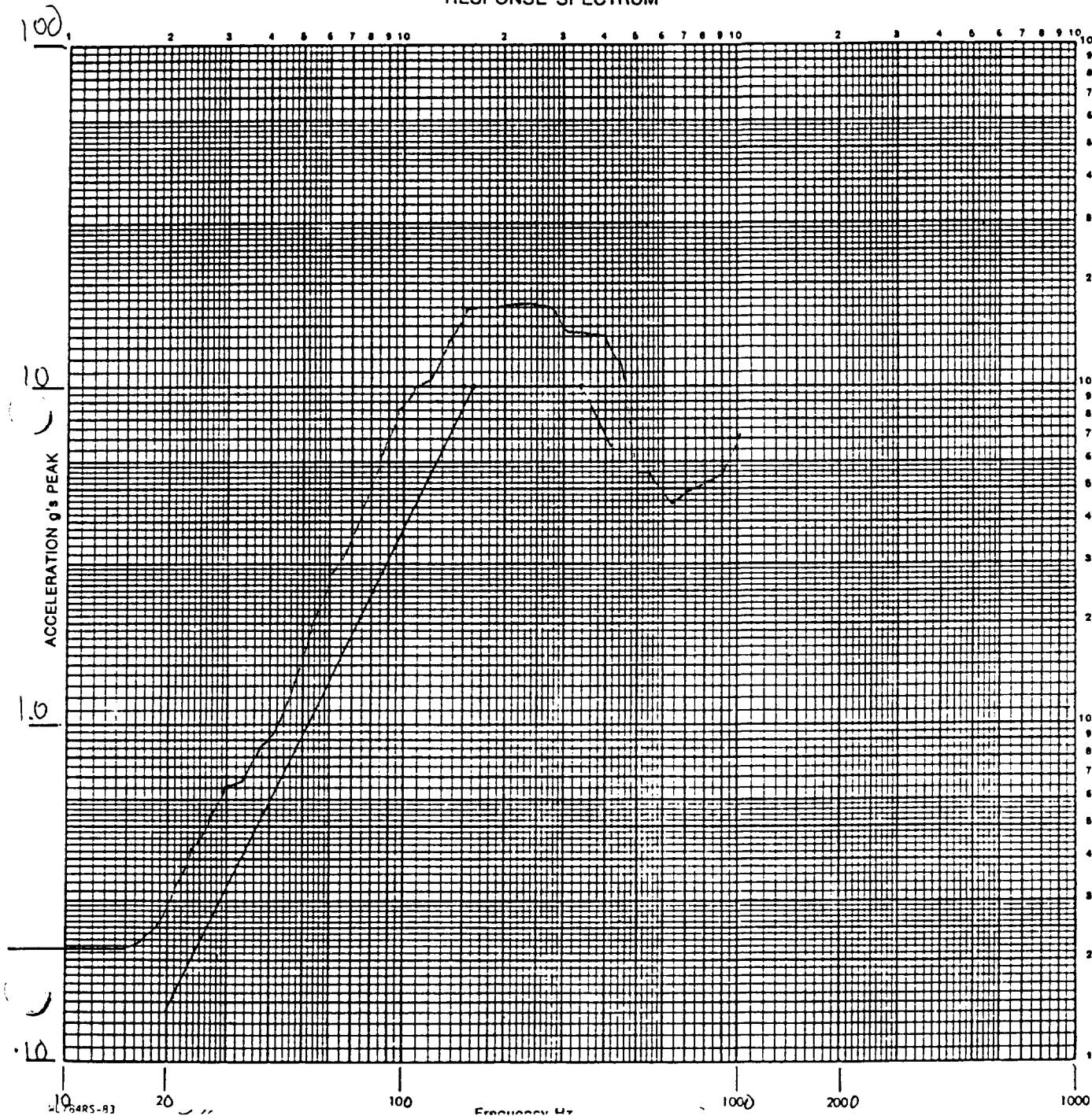
CUSTOMER MTI Job No. 53976 Date 2-25-89
Specimen TRANSPORTATION UNIT #2 Axis of Test Long
Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. #5
Operator ma Engineer C Chen -20°F

RESPONSE SPECTRUM



CUSTOMER MTI Job No. 53976 Date 3-6
2-25-85
Specimen TRANSPORTATION UNIT #2 Axis of Test Long
Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. 1 CCL
Operator MCH Engineer CCL AMB

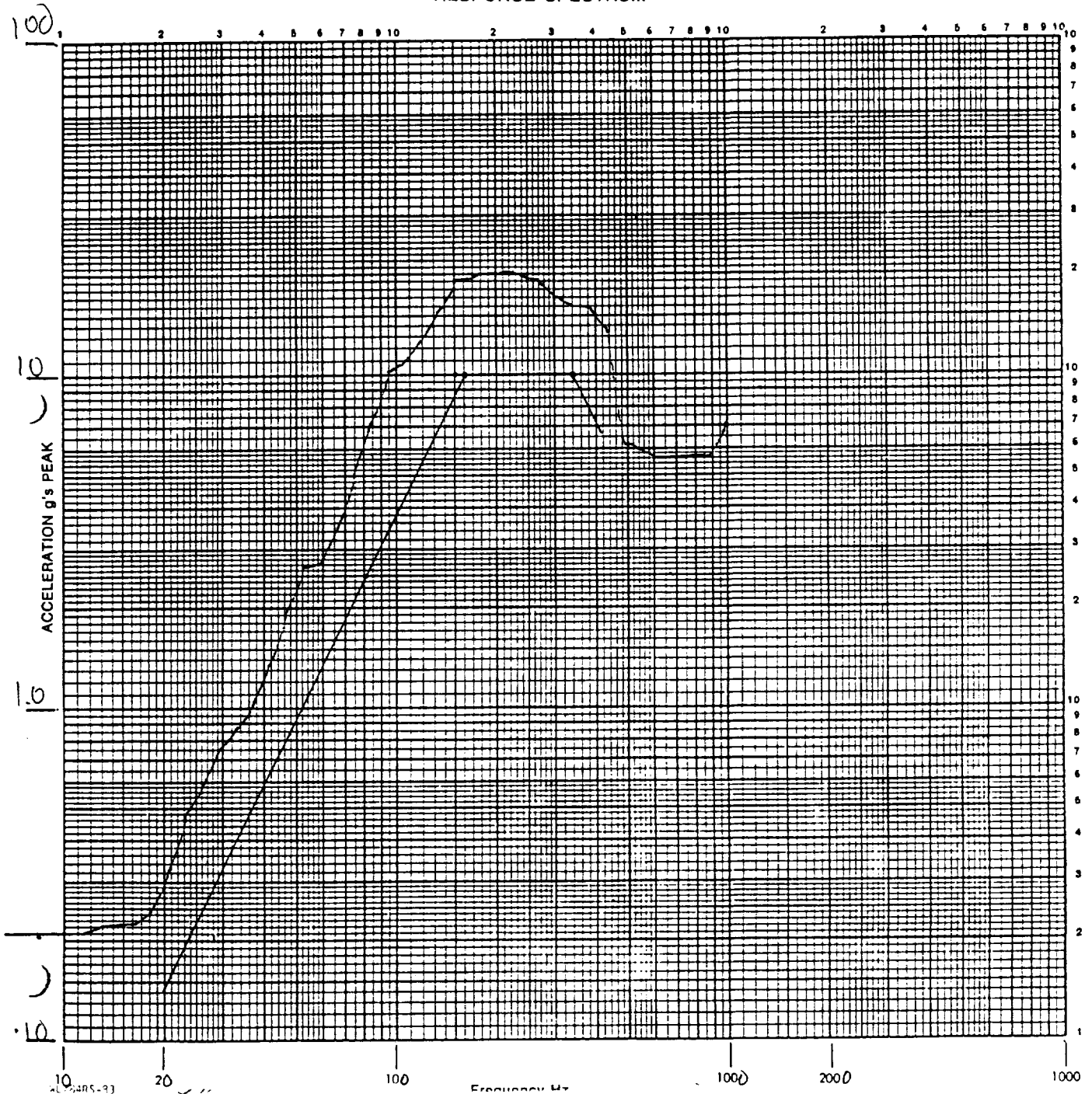
RESPONSE SPECTRUM



3-6

CUSTOMER MTI Job No. 53976 Date 2-25-89
Specimen TRANSPORTATION UNIT #2 Axis of Test Long
Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. 32
Operator MA Engineer CC AMB

RESPONSE SPECTRUM



CUSTOMER MTI Job No. 53976 Date 3-6-85
2-25-85

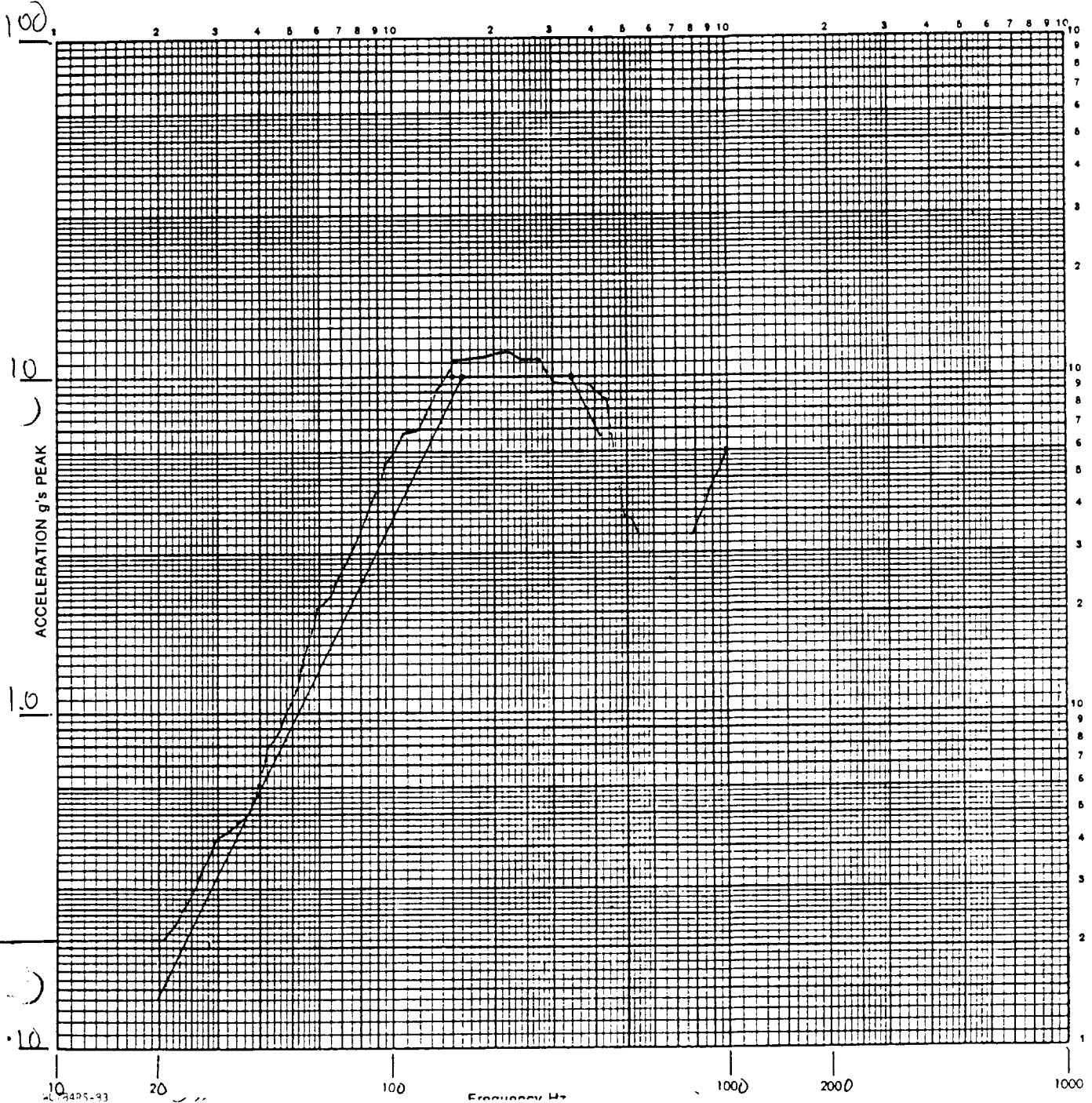
Specimen TRANSPORTATION UNIT #2 Axis of Test Long

Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()

Full Scale 100 g Damping 5 % Run No. 3

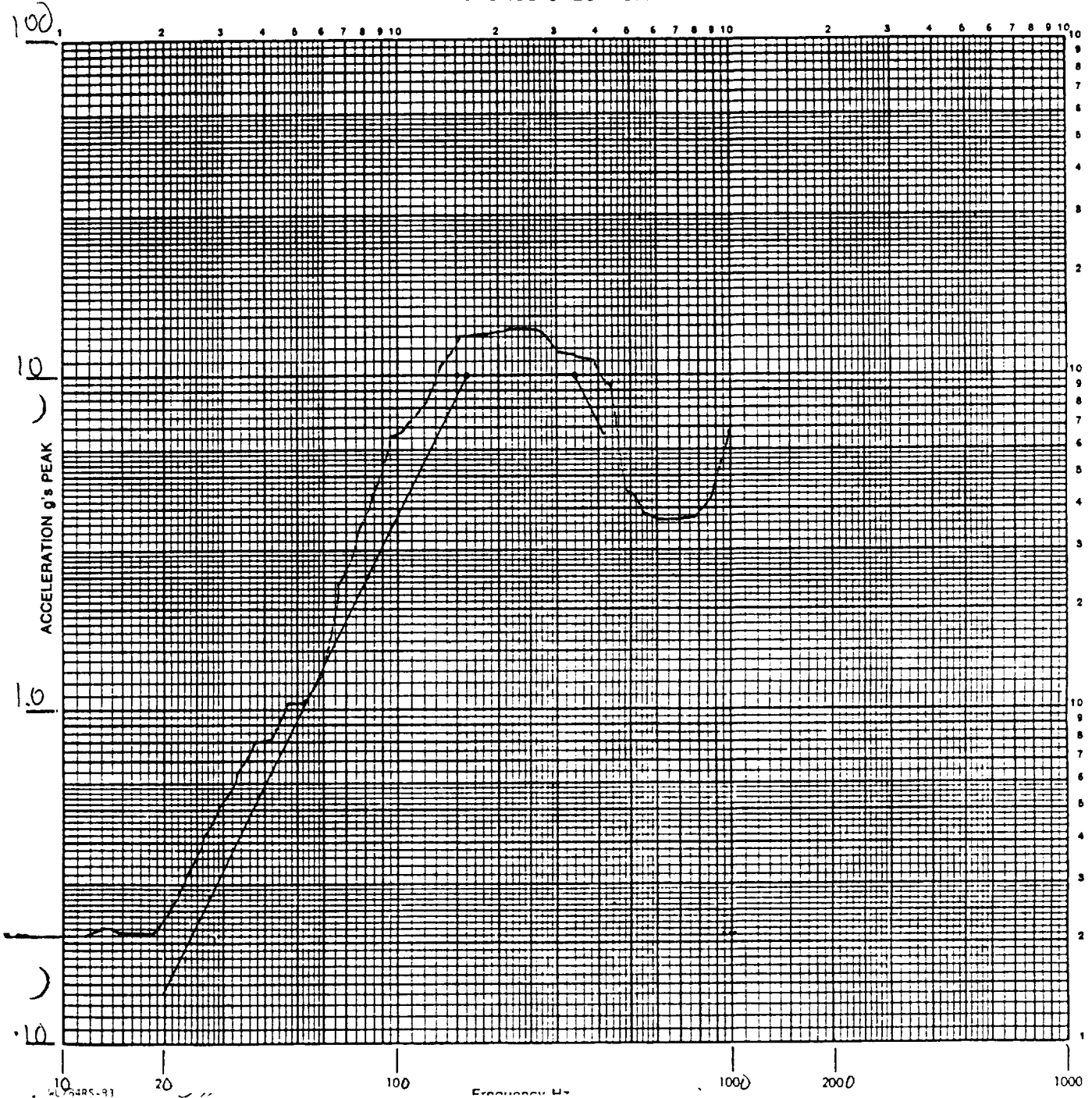
Operator MC Engineer CC AMB

RESPONSE SPECTRUM



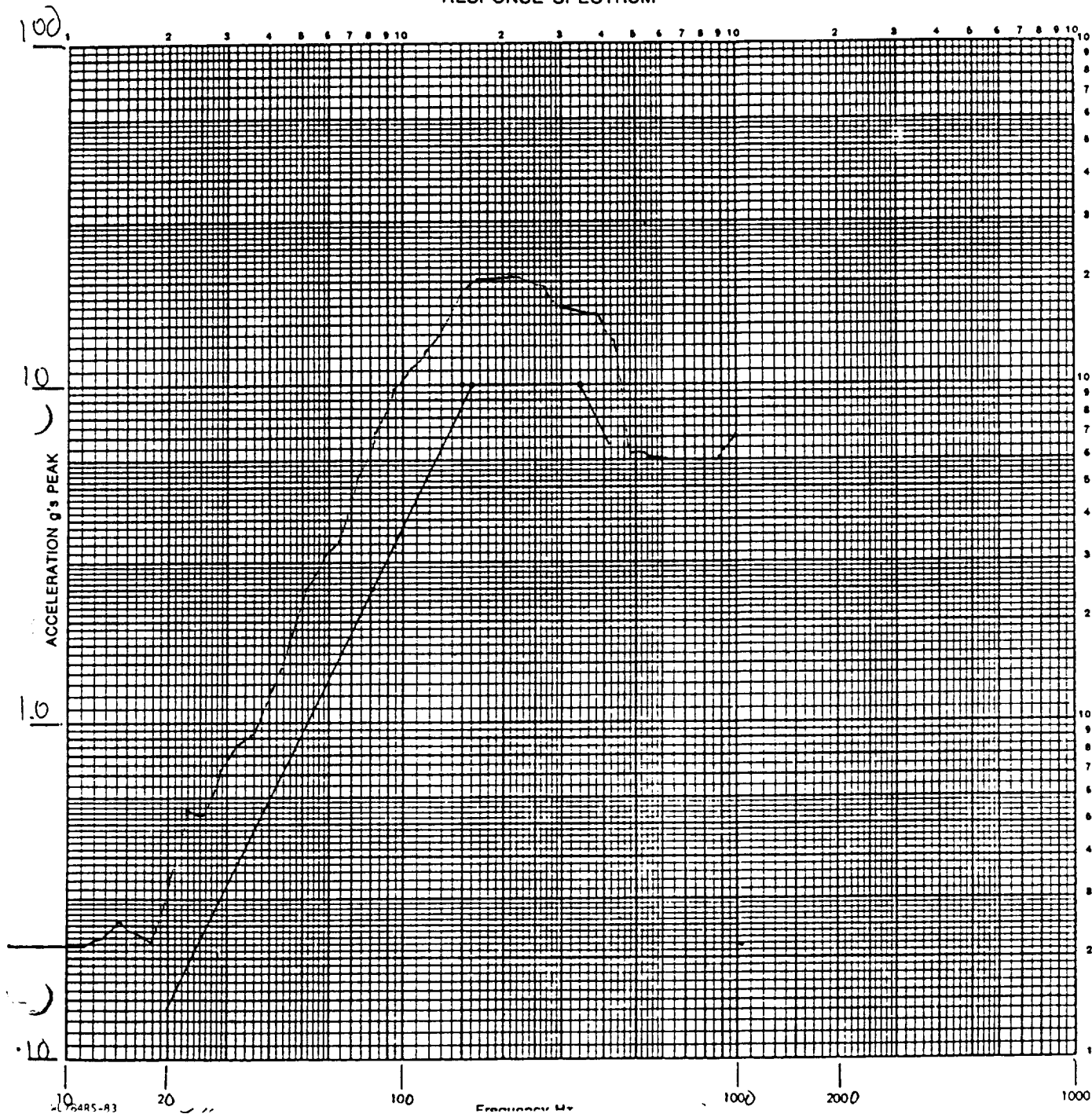
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Specimen TRANSPORTATION UNIT #2 Axis of Test LONG
Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. SHOCK #4
Operator Man Engineer ccm AMB

RESPONSE SPECTRUM



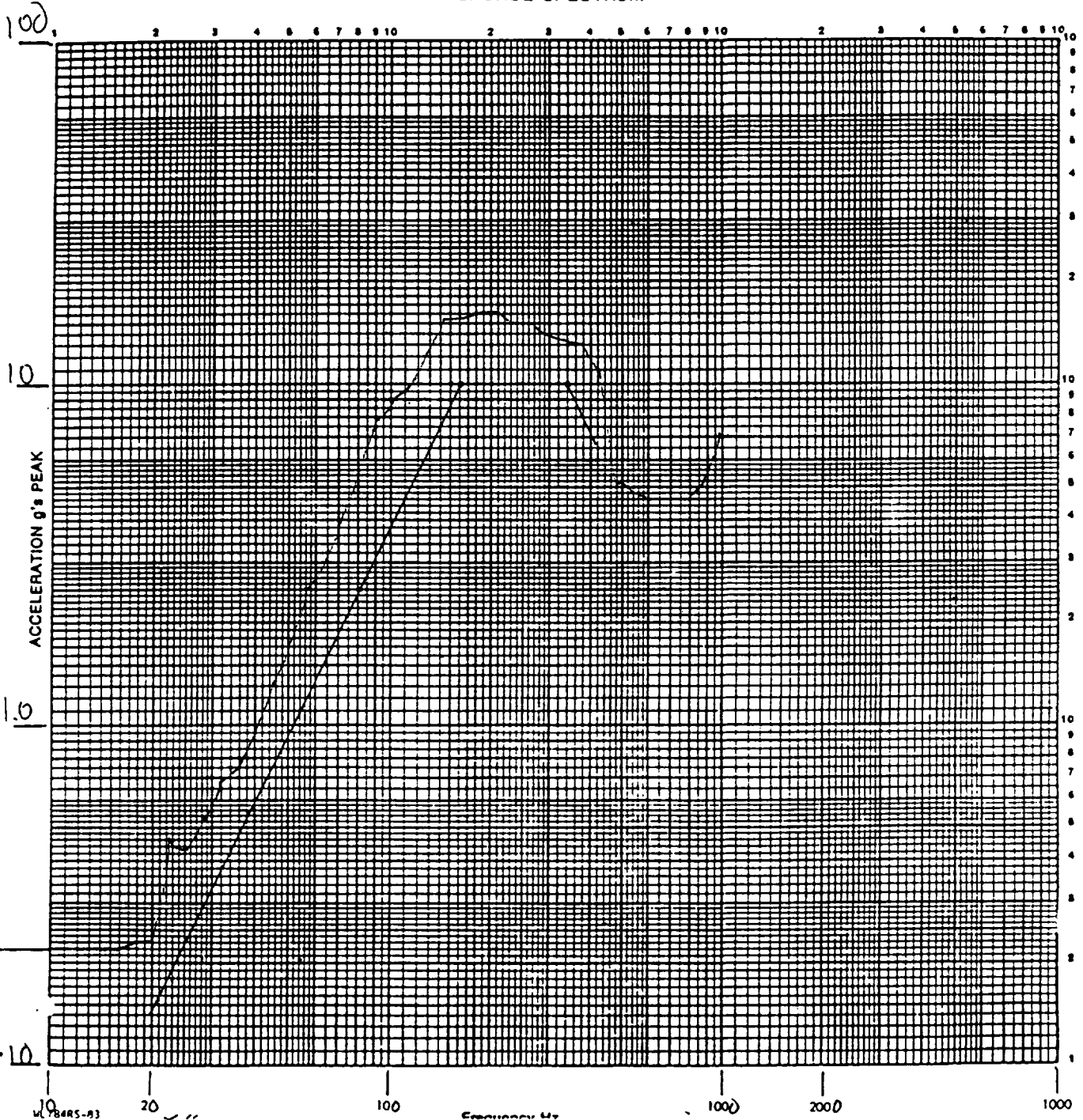
CUSTOMER MTI Job No. 53976 Date 3-6-89
Specimen TRANSPORTATION UNIT #2 Axis of Test Long
Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. 5
Operator MAC Engineer CCH AMB

RESPONSE SPECTRUM



CUSTOMER MTI Job No. 53976 Date 3-6-89
Specimen TRANSPORTATION UNIT #1 Axis of Test Lag
Accel. No. 1 Axis Long Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. 1
Operator M. Ch Engineer C. Ch AMPB

RESPONSE SPECTRUM



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CUSTOMER MTI

Job No. 53976

Date 6-6-89

Specimen TRANSPORTATION UNIT #1

Axis of Test Long

Accel. No. 1 Axis LONG Control (☒) Response () OBE () SSE () DBE ()

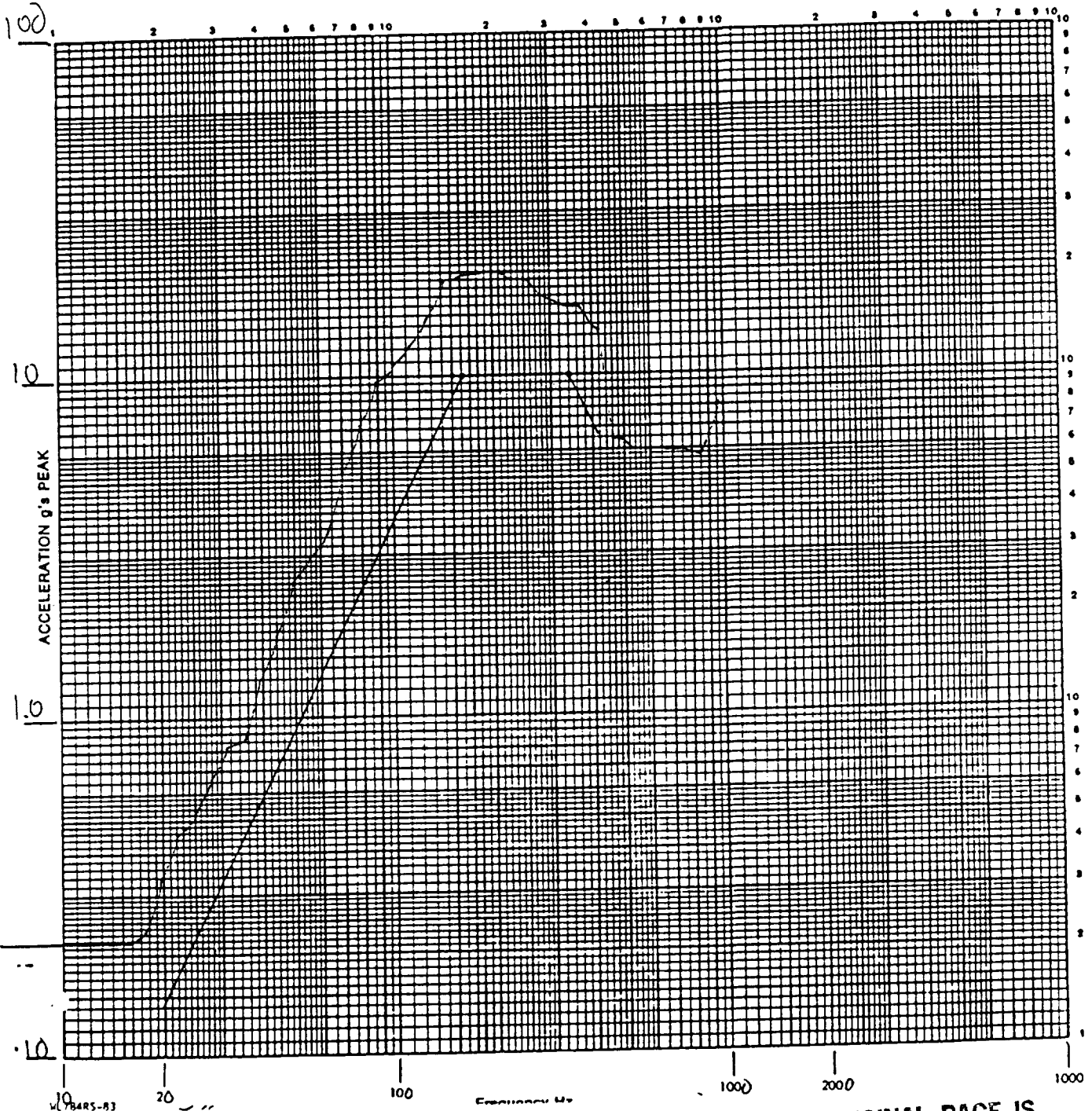
Full Scale 100 g Damping 5 %

Run No. 2

Operator MO Engineer CCH

Long - A+B

RESPONSE SPECTRUM



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WYLE
LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

CUSTOMER MTI

Job No. 53576

Date 3rd 6-6-89

Specimen TRANSPORTATION UNIT #1

Axis of Test Long

Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()

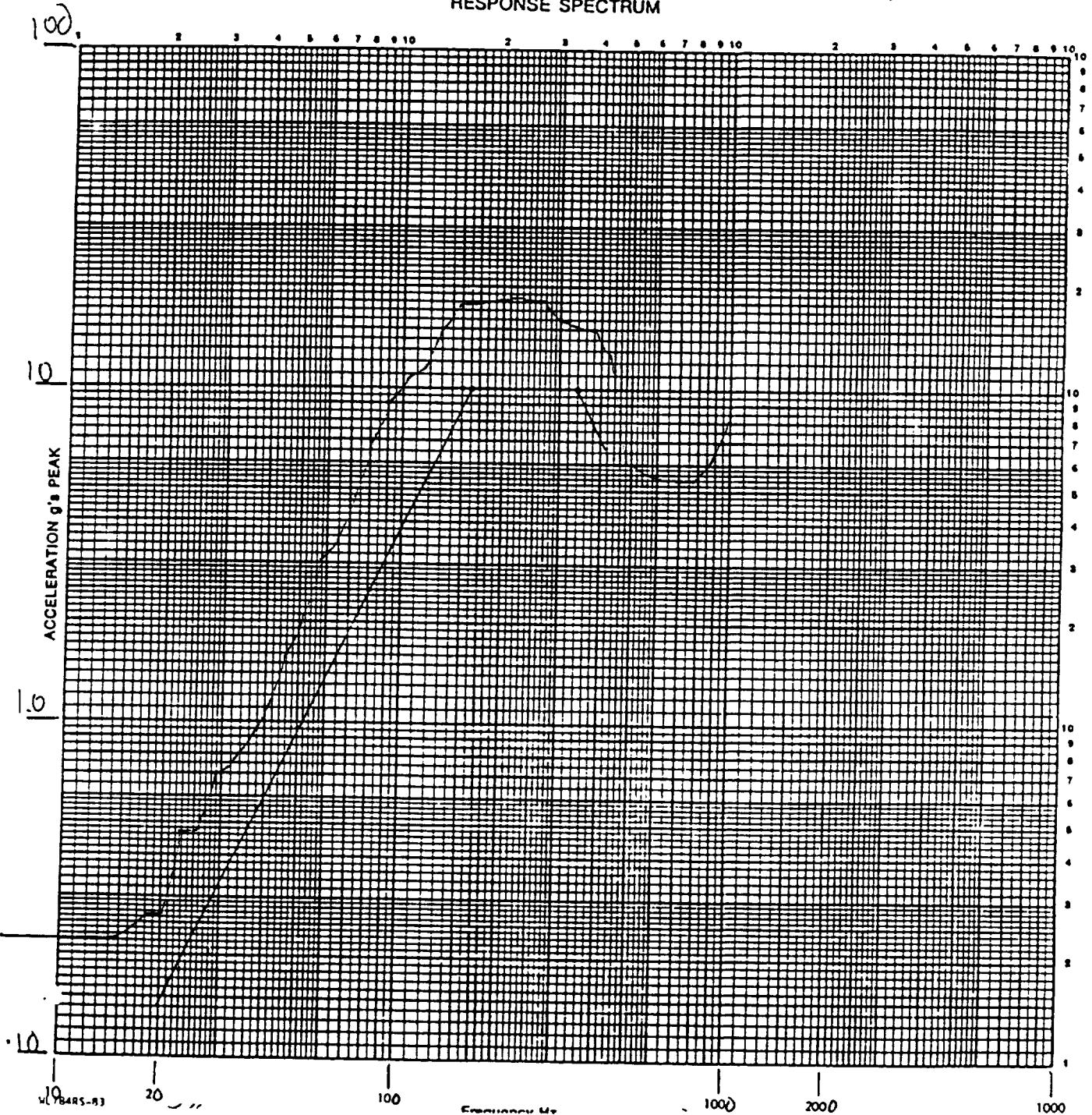
Full Scale 100 g Damping 5 %

Run No. 3

Operator Man Engineer CC

AMB

RESPONSE SPECTRUM



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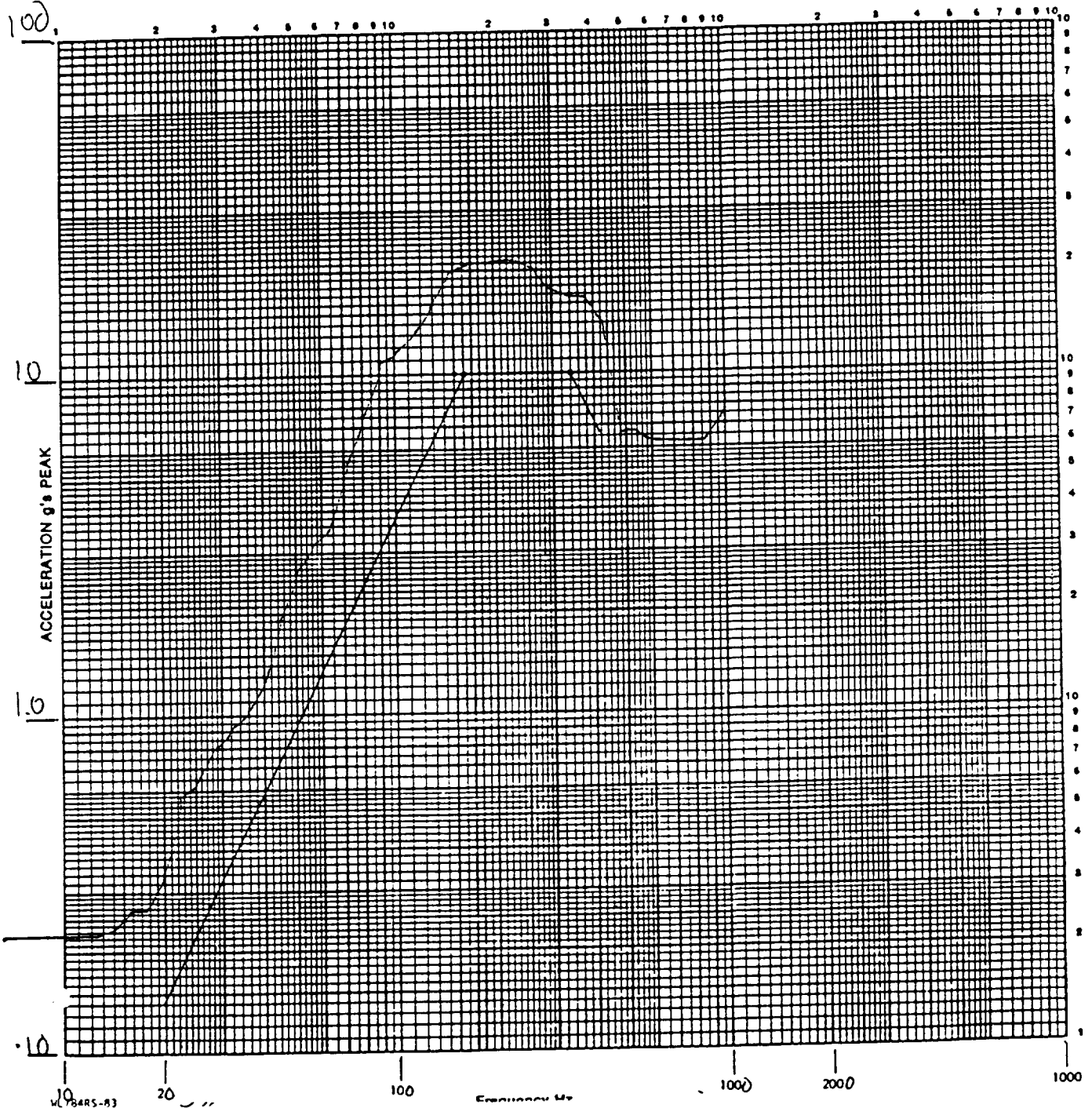
Report No. 53976

WYLE
LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

Page No. 65

CUSTOMER MTI Job No. 53976 Date 3-6-68
Specimen TRANSPORTATION UNIT #1 Axis of Test Long
Accel. No. 1 Axis Long Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. 4
Operator MC Engineer to CCH AMB.

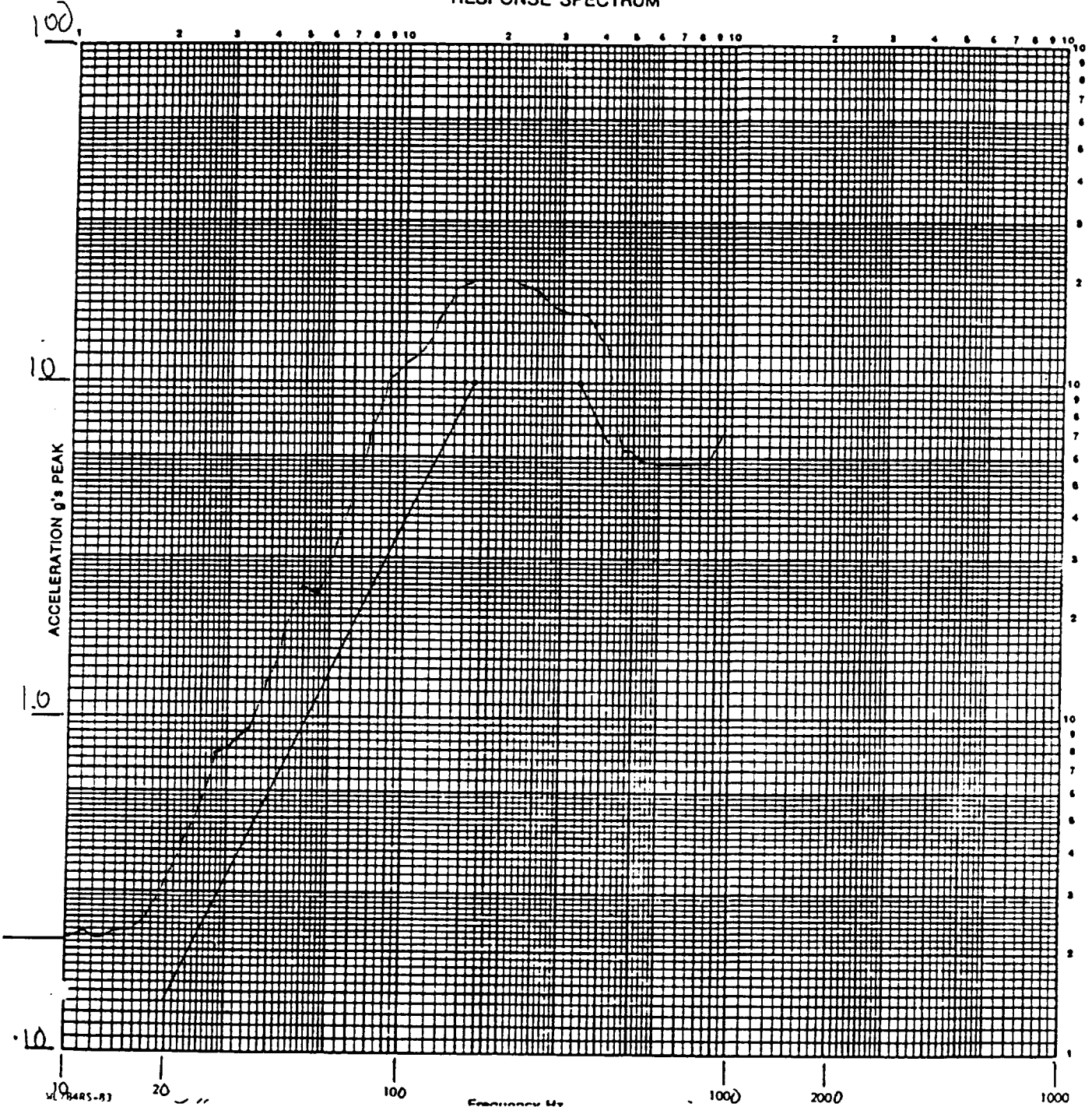
RESPONSE SPECTRUM



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CUSTOMER MTI Job No. 53976 Date 3-6-89
Specimen TRANSPORTATION UNIT #1 Axis of Test Long
Accel. No. 1 Axis LONG Control (/) Response () OBE () SSE () DBE ()
Full Scale 100 g Damping 5 % Run No. 5
Operator MC Engineer LONG CCH AMB

RESPONSE SPECTRUM



TEST TITLE TRANSPORTATION & FUNCTIONALITY / Shock

CUSTOMER MORTON THOMAS Job No. 53976 Date 2-28-89
Specimen TRANSPORTATION UNIT Technician W. C. C.
Part No. 7700TYPE Serial No. 1-12 Engineer C. C. C.

Report No. 53976

Page No. 67

EQUIPMENT	MANUFACTURER	MODEL NO.	RANGE	WYLE NO.	CALIBRATION		ACCY.
					LAST	DUE	
ACCELEROMETER	ENDRECO	7704-50	0 - 1000 g.	10166	1-16-89	4-16-89	$\pm 2\%$
ACCELEROMETER	ENDRECO	7704-50	0 - 1000 g.	10450	1-16-89	4-16-89	$\pm 2\%$
ACCELEROMETER	ENDRECO	7704-50	0 - 1000 g.	10165	1-16-89	4-16-89	$\pm 2\%$
ACCELEROMETER	ENDRECO	7704-50	0 - 1000 g.	10447	1-16-89	4-16-89	$\pm 2\%$
Charge Amplifier	UNIVATE DICKER	D-22	0 - 1000 g.	10675	9-6-88	3-9-89	$\pm 2\%$
Charge Amplifier	UNIVATE DICKER	D-22	0 - 1000 g.	10673	9-6-88	3-9-89	$\pm 2\%$
Charge Amplifier	UNIVATE DICKER	D-22	0 - 1000 g.	10674	9-6-88	3-9-89	$\pm 2\%$
Charge Amplifier	UNIVATE DICKER	D-22	0 - 1000 g.	10654	9-6-88	3-9-89	$\pm 2\%$
VOLT METER	Bjk	2416	01 - 1000V.	30813	12-21-88	4-16-89	$\pm 5\%$
Oscilloscope	LEADER	514A	DUAL TRACE	9621	Prior to use		
Power Amplifier	Ling	9P200/350	200KW	31346	N/A	N/A	N/A
Exciter	Ling	249	5 - 2000 Hz.	6702	N/A	N/A	N/A
Digital Control Sys.	SPECTRUM DYNAMICS	1500	30,000 FORCE LB.	10640	Prior to use		
TEMP. Recorder	Ling		5 - 2000 Hz.				

Where applicable, the listed test equipment has been calibrated using standards which are traceable to the National Bureau of Standards. Certificates and reports of all calibrations are retained in the Wyle Laboratories files and are available for inspection upon request.

QA Form Approval SA
W614D-82

NOTICE OF DEVIATION

WYLE
LABORATORIES

WYLE JOB NO.	DE 53976
NOD NO.	1
PO NO.	9MG021
DATE	10 March 1989
GOV'T. CONT. NO.	NA58-30490

TO: MORTON THIOKOL, INC.ATTN: Miles BrownPART NAME Transportation Monitoring UnitPART NO. Prototype SERIAL NO. Test Unit No. 1TEST: Transportation Vibration, ambient temperature, longitudinal axisSPECIFICATION MTI Doc. CTP-0097, Rev. B PARAGRAPH NO. 8.2NOTIFIED CUSTOMER: Charlie Mondall DATE: 7 March 1989 VIA: In personNOTIFIED DCAS-QAR: Not required DATE: _____

SPECIFICATION REQUIREMENTS:

Subject specimens to transportation vibration test.
Visually inspect test specimens for physical damage.

DATE OF DEVIATION: 6 March 1989
TYPE OF DEVIATION: Specimen anomaly
DESCRIPTION OF DEVIATION:

During ambient temperature transportation vibration resonance dwell test at first mode (14.5 Hz, 1.2g input) resonance, structural damage was noted on the test specimen. The bottom mounting plate was fractured, and several mounting screws came loose.

SPECIMEN DISPOSITION: Test was discontinued.

COMMENTS - RECOMMENDATIONS:

DISTRIBUTION:

ORIGINAL: DEPARTMENT
3 COPIES: CUSTOMER
1 COPY : DEPARTMENT
1 COPY : QUALITY CONTROL
1 COPY : CONTRACTS
0 COPIES: DCAS-QAR

TEST WITNESS: _____ TEST ENGINEER C. C. LeeREPRESENTING _____ DEPT. MANAGER J. B. AndersonQUALITY ASSURANCE J. G. GraperQC FORM APPROVAL Pf

NOTICE OF DEVIATION**WYLE**
LABORATORIES

WYLE JOB NO.	DE 53976
NOD NO.	2
PO NO.	9MG021
DATE	6 April 1989
GOV'T. CONT. NO.	NAS8-30490

TO: MORTON THIOKOL, INC.

ATTN: Miles Brown, Purchasing

PART NAME: Transportation Monitoring Unit

PART NO. Prototype SERIAL NO. Units 1 and 2

TEST: Transportation Vibration, +163F

SPECIFICATION MTI QTP CTP-0097 PARAGRAPH NO. 8.2

NOTIFIED CUSTOMER: Charlie Mondale DATE: 5 April 1989 VIA: In person

NOTIFIED DCAS-QAR: Not required

DATE:

SPECIFICATION REQUIREMENTS:

Subject test specimen to transportation vibration test at 163F. Specimen shall remain functional during test.

DATE OF DEVIATION: 5 April 1989
 TYPE OF DEVIATION: Specimen anomaly
 DESCRIPTION OF DEVIATION:

Both test specimens stopped functioning at approximately +150F temperature.

SPECIMEN DISPOSITION: Test was discontinued.

COMMENTS - RECOMMENDATIONS:

DISTRIBUTION:

ORIGINAL: DEPARTMENT
 3 COPIES: CUSTOMER
 1 COPY : DEPARTMENT
 1 COPY : QUALITY CONTROL
 1 COPY : CONTRACTS
 0 COPIES: DCAS-QAR

TEST WITNESS: TEST ENGINEER

REPRESENTING: DEPT. MANAGER

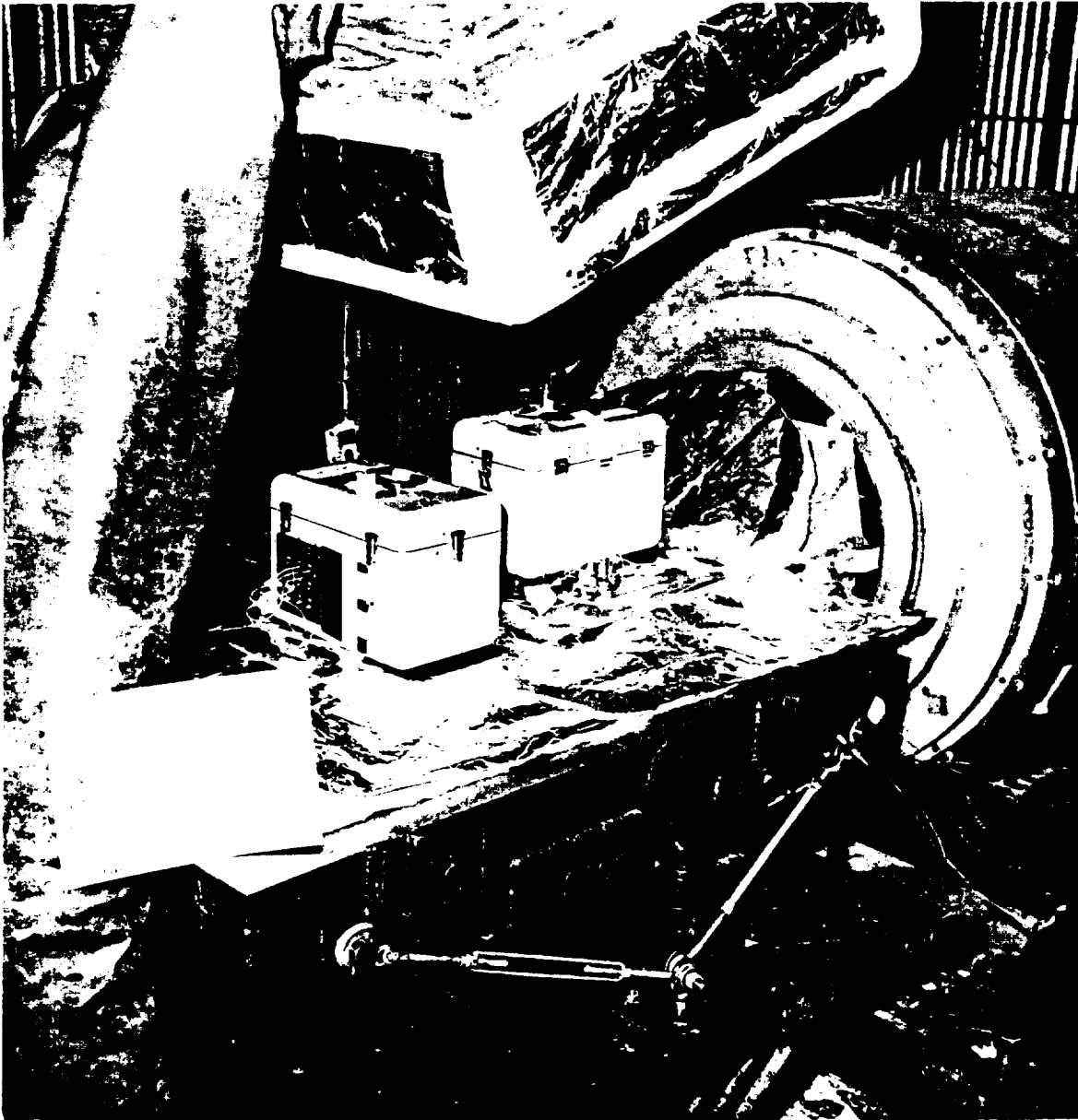
QUALITY ASSURANCE

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OF POOR QUALITY

Report No. 53976

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ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH



PHOTOGRAPH 1

TRANSPORTATION VIBRATION TEST SETUP
LONGITUDINAL AXIS (Typical)

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Report No. 53976

Page No. 72

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH



PHOTOGRAPH 2

BROKEN MOUNTING PLATE ON TEST UNIT NO. 1
(Reference Notice of Deviation No. 1)

APPENDIX B

Unisys Final Test Report for Qualification Testing of Thiokol's Transportation Monitoring Unit

REVISION _____
90467-1.25

DOC NO	TWR-18782	VOL
SEC	PAGE	B1

**UNISYS
FINAL TEST REPORT
FOR
QUALIFICATION TESTING
OF
THIOKOL'S
TRANSPORTATION MONITORING UNIT**

UNISYS FINAL TEST REPORT
QUALIFICATION TESTING ON THIOKOL'S
TRANSPORTATION MONITORING UNIT

R. C. NYBO
R. C. NYBO

ENVIRONMENTAL LAB MANAGER

H. VARD LEANY

TEST ENGINEER

H. Vard Leany

Brad Gallon
UNISYS QUALITY ASSURANCE

BRAD GALLON

TABLE OF CONTENTS

1.0	INTRODUCTION	4
2.0	DETAILED TEST LOGS	4
2.1	FACILITY LOG	5
2.2	DAILY ACTIVITY LOG UNISYS QUALITY ASSURANCE	7
3.0	TEST RESULTS	14
3.1	ADDITIONAL TMU TESTING	14

APPENDICES

APPENDIX A	TRANSPORTATION MONITORING UNIT SYSTEM TEST PROCEDURE STP-360-A	A1 - A6
APPENDIX B	UNISYS CONTROL AND RESPONSE DATA FROM LONGITUDIAL AXIS TRANSPORTATION TEST (-40°F ± 10°F)	B1 - B11
APPENDIX C	UNISYS CONTROL AND RESPONSE DATA FROM TANGENTIAL AXIS TRANSPORTATION TEST (-40°F ± 10°F)	C1 - C11
APPENDIX D	UNISYS CONTROL AND RESPONSE DATA FROM TANGENTIAL AXIS TRANSPORTATION TEST (-70°F ± 10°F)	D1 - D13
APPENDIX E	UNISYS CONTROL AND RESPONSE DATA FROM LONGITUDIAL AXIS TRANSPORTATION TEST (-70°F ± 10°F)	E1 - E12
APPENDIX F	UNISYS CONTROL AND RESPONSE DATA FROM LONGITUDIAL AXIS TRANSPORTATION TEST (-163°F ± 10°F)	F1 - F13

1.0 INTRODUCTION

Qualification testing of the Thiokol Transportation Monitoring Units (TMU) was started on November 8, 1989. The testing was conducted in accordance with Thiokol's document CFP-0097 Rev. D. A detailed test procedure was written by Unisys Corp. STP-360 Rev. A.

The TMU's were started on November 8, 1989 to begin the required non-stop operation of 17 days running time. Due to fixturing problems and facility scheduling problems the actual shaking of the TMU's didn't start until November 20, 1989.

The testing was observed by a Thiokol Engineer at all times during the testing procedure.

The Qualification testing was set up to be conducted in two parts. The first part was a transportation test, to determine if the TMU System would withstand the intended environment. The second part was a functional test to determine the accuracy of the TMU System. The second part of the test was never conducted due to the system failures described in Section 3.0.

2.0 DETAILED TEST LOGS

There are two test logs which were kept during the qualification testing of the Thiokol transportation monitoring units. The first is a facility log kept by the test engineer of all the activity that occurred on the shaker. The second test log was kept by the Thiokol engineering representative of all activities that occurred during the entire test procedures. This second log was also used by Unisys Quality assurance to ensure that all the activities accomplished by Unisys were according to Thiokol's (TP-0097-1).

2.1 FACILITY LOG

2.2 DAILY ACTIVITY LOG UNISYS QUALITY ASSURANCE

2.1

FACILITY LOG

UD1-9818

FACILITY: C-200		ENVIRONMENTAL DATA SHEET ENVIRONMENTAL LABORATORY — DEPT. 9253			
A.O.		ENV. TECH.		TEST SCHED.	
ENGINEER OR Q.C.		PHONE		TEST COMPLETED	
TECHNICIAN		PHONE		TEST REMOVED	
UNIT TITLE TRANSPORTATION MONITOR UNIT		SER. 7, 17	QTY.	TOTAL UTILIZATION	
INSTRUCTIONS TO OPERATOR		TEST TO TERMINATE: BY:			ENVIRONMENTAL LABORATORY SUPERVISORS APPROVAL
TEST TEMPERATURE/VIBRATION					SIGNATURE
SPEC.					DATE
PAR.					
DATE	TIME	CHRONOLOGICAL RECORD OF TEST			INITIALS (PRINT)
11:17	10:00	Began mounting TMU on Vib. fixture in the Longitudinal Axis			HVL
	13:39	Finished mounting TMU on Vib. fixture			HVL
	14:30	Sealed shroud over TMU			HVL
11:20	6:45	Began conditioning TMU to -40F			HVL
	12:59	Raised shroud to install response accel. and verify operation of TMU			HVL
	15:20	Began Sine Sweep Test (5-2000-5 Hz)			HVL
	15:57	Began Res. Dwell at 46 Hz to 54 Hz			HVL
	16:13	Began Res. Dwell at 95 Hz			HVL
	19:39	Performed shock test per specified spectra (5 shocks)			HVL
	20:30	Raised shroud, returned TMU to room temp.			HVL
11:21	7:19	Began to change TMU from Longitudinal to Lateral Axis			HVL
	9:35	Began conditioning TMU to -40°F in the Lateral Axis			HVL
	14:18	Began Sine Sweep Test (5-2000-5 Hz)			HVL
	14:41	Began Res Dwell at 38 Hz			HVL
	15:00	Performed shock test per specified spectra (5 shocks)			HVL
	17:23	Raised shroud, returned TMU to Ambient Temp.			HVL
11:22	9:55	Finished changing shock mounts			HVL
	10:07	Began Sine Sweep Test (5-2000-5 Hz) 70°F Lat. Axis			HVL
	10:43	Began Sine Dwell at 26 Hz			HVL
	11:01	Began Sine Dwell at 86 Hz			HVL
	13:08	Performed shock test per specified spectra (5 shocks)			HVL
VERIFIED & RELEASED BY: _____ Q.C. OR PROGRESS _____ COGNIZANT ENGINEER _____					

2.2

DAILY ACTIVITY LOG

UNISYS QUALITY ASSURANCE

QUALIFICATION TEST LOG FOR TMU
TMU'S #7 AND #17
IN ACCORDANCE WITH CTP-0097.

TMU #7 Qualification Unit
TMU #17 Thiokol Engineering Evaluation Unit

Memory Mod	<u>1</u>	<u>2</u>
TMU #7	0000004	0000024
TMU #17	0000013	0000021

Date	Time	
11-8-89	11:20	- Memory module check - Ok
11-8-89	11:30	- Battery check of TMU #7 & #17.
		- All packs measured 9.37 volts.
	11:37	- System self check on #7 Ok
	11:44	- System self check on #17 Ok
	11:57	- Started both TMU's (#7 & #17).
	12:00	- 3 minute timed event.

UNISYS
15
FINAL
TEST

R.S. Bergen

R.S. Bergen Unisys Quality Assurance
Phone - 594-7614

11-9-89	12:00	- Observed recorder red light (#1 Recorder) illuminate for approximately 11 seconds on both S/N 0007 and S/N 0017 of QDLM-2 Acceleration Monitor System.
	13:00	- Moved #17 to shake table for fitting.

UNISYS
15
FINAL
TEST

R.S. Bergen

11-10-89	14:45	- Returned #17 back to lab table
11-10-89	11:59:54	- 6-hour timed event occurred: Observed recorder red light (#1 recorder) illuminated for approximately 10 seconds on both S/N 0007 and S/N 0017 of QDLM-2 Acceleration Monitoring System.

UNISYS
15
FINAL
TEST

R.S. Bergen

11-10-89	14:36	- Moved Box 0017 to test fixture
11-10-89	15:12	- Replaced Box 0017.

11-13-89	11:59	- Observed recorder #1 red light illuminate for S/N 0007 only of QDLM-2 acceleration monitoring system. S/N 0017 was turned off 1158 for removal of recording modules (#1000013 #2 & 21. Replace original modules with recorder #1 S/N 000014 and recorder #2 S/N 000035. Started unit #0017 at 1202.
----------	-------	---

UNISYS
15
FINAL
TEST

R.S. Bergen

TEST CONTINUING

11-13-89	15:14	- Checking and sealing trigger channels on both boxes also sealing temperature channels CFM.
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11-14-89	11:58:41	- Observed recorder #1 red light illuminate for approximately 10 seconds for QDLM-2- Acceleration monitoring system S/N 0007. S/N 0017 Recorder #1 Red light illuminated and then extinguished at 12:01:30. Test Continuing
----------	----------	---

UNISYS
15
FINAL
TEST

R.S. Bergen

11-14-89 12:45 - Moved TMU's to check fixture to ensure proper set up
 13:10 - Moved TMU's back to table in safe while fixturing was being completed.

11-15-89 11:57:35 - Observed recorder #1 Red Light illuminate for approximately 11 seconds for QDLM-2 acceleration monitor system S/N0007.



12:03:10 - Observed recorder #1 Red Light illuminate for approximately 10 seconds for QDLM-2 Acceleration Monitor System S/N 0017.



TEST CONTINUING:

11-16-89 11:57.05 - Observed Recorder #1 Red Light illuminate for approximately 10 seconds for QDLM-2 acceleration monitor system S/N 0007.



12:02:38 - Observed Recorder #1 Red Light Illuminated for approximately 11 seconds for QDLM-2 acceleration monitor system S/N 0017.



TEST CONTINUING:

11-17-89 10:00:00 - Started to mount hardware on shaker this movement and operation may cause some non-real events.

13:39:00 - Finished installation of TMU's 0017, 0007 to shaker. Disregard any events on 11-16-89 between 10:00:00 - 13:39:00.

CFM

14:30 - Sealed UUTS within shroud.



11-20-89 06:45 - Shroud put into conditioning stable around -35°.

12:59 - Unsealed shroud and verified operation of both units. Total out-of-condition period 25:50 min/sec. make up conditioning shall be 45 minutes.



- Longitudinal transportation test -40°F ± 10°F.

14:10 - Conditioning tone made up. CFM
Longitudinal Sine Sweep -40°F.
 - Starting Longitudinal cold Sine Sweep -40°F

15:20 - 5-2000-5 at 1 Oct/Min - CFM.
 Resonant frequencies - 46 Hz 95 Hz



15:38 - Completed Sine Sweep

Longitudinal cold dwells -40°F

15:51 - Started 1st Sine Dwell 46 Hz hold for 15 min.
 2 min. 46 Sec. Chased Peak to 54 Hz.
 2.5 G's to 2.7 G's. .015 Disp.

16:13 - Started 2nd Sine Dwell 95 Hz Hold for 15.
2.5 G .0055 Disp.
Longitudinal Shocks -40°F

19:39 - Preformed shock No. 1 CFM

20:16:38 - Preformed Shock No.2. CFM

20:20:53 - 3rd Shock CFM

20:25:03 - 4th Shock CFM

20:29:07 - 5th Shock CFM

20:30:00 - Lifted shroud and verified TMU operation. Both
TMU's still operating shutting down for the evening. CFM

11-21-89 07:19 - Started moving into tangential axis. Disregard any
events until operation is completed. CFM

08:40:00 - Stopped box 0017 to look at data. CFM

08:48:00 - Started Box 0017 QSTH - new memory
Modules 007 - Slot 1 0038 - Slot 2 CFM

08:51:00 - 3 Minute Event occurred. CFM

08:59:00 - Completed Axis turn system now in Tangential Axis. CFM

09:20:00 - Pictures of Tangential setup

09:35:00 - Conditioning started. Tangential Axis cold -40

10:00 - Reviewed test data obtained on 11/20 with the
electrical engineer that performed the tests.
Verified that the test data correlate with the
requirements of the test procedure.



TANGENTIAL AXIS TRANSPORTATION TEST -40°F ± 10°F.

TANGENTIAL AXIS SINE SWEEP -40°F

14:18 - Started Tangential Sine Sweep (cold)

14:39 - Completed Sine Sweep 5-2000-5
38 Hz, 4.8 G's = DA = .07

14:41:00 - Started 38 Hz Resonance Dwell 4.8 G's .07 Disp.

14:56:00 - End Dwell. Only one resonant point Dwelled.
 15:00 - Started First Shock - Tangential Axis (cold)
 15:05 - Started Second Shock
 15:09 - Third Shock
 15:13 - Fourth Shock
 15:17 - Fifth Shock

11-22-89 08:30 - The test data obtained on 11-20-89 was re-reviewed by the Unisys Electrical engineers that performed the testing. It was determined that the Shock Spectra Tests were performed to the wrong tolerances. The actual tolerance was +40% to -30% and should have been +40% to -20%. This testing error occurred while the TMU's were in the longitudinal axis, at -40°F. This test will be repeated and documented by test data to verify implementation of the correct test tolerance.



Bjgollon

11-22-89 08:30 - Qualification TMU #0007 shut down over night due to low batteries. This is a failure of the Qualification test because the TMU only ran for 14 days, and not the required 17 days. Thiokol Corporation informed NASA and it was agreed to restart TMU #0007 and continue testing. CFM

11-22-89 09:20 - TMU #7 Qualification Unit was restarted with Unisys QA to Verify. New Memory Mod 7 2
 TMU #7 0000013 0000021
 New batteries checked out OK. Both at 9.37V. System self check - OK. Light flashing every 5 seconds.

Observed recorder red light illuminate for 11 seconds on TMU S/N 7 upon restart after battery replacement





Bjgollon

TMU Transportation Test Tangential Axis
 70°F ± 10°F.

TANGENTIAL AXIS SINE SWEEP - 70°F

- 10:07 - Started sine sweep in the lateral axis (or Tangential). 70°F.

TANGENTIAL AXIS SINE DWELLS - 70°F

- 10:30 - Completed Sine Sweep 5-2000-5.
- 10:43 - Started 26 Hz Resonance Dwell 16G's = DA = 4 inch.
- 10:58 - Completed 26 Hz Dwell.
- 11:01 - Started 86 Hz Resonance Dwell 3.5G = DA = >0
- 11:16 - Completed 86 Hz REsonance Dwell.
Tangential Axis Shocks 70°F
- 13:08 - Started first shock
- 13:11 - Second Shock
- 13:22 - Third Shock
- 13:27 - Fourth Shock
- 13:32 - Fifth Shock
- 14:00 - Observed both TMU's to verify LEDs flashing at 5 second interval and sealed the shroud for the weekend.  *Bjgallen*
- 11-27-89 08:30 - Removed seals from shroud and verified both LEDs flashing at 5 second intervals. Unisys Electrical Engineers began changing TMUs to the longitudinal axis for testing at +70°F.  *Bjgallen*
- 10:20 - Finished Rotation of test article preparing the longitudinal Sine Sweep.

TMU Longitudinal Transportation Test
+70°F ± 10°F.
Longitudinal Sine Sweep - 70°F
- 10:38 - Started Sine Sweep - 5-2000-5 Hz
- 11:02 - Finished Sine Sweep - 1 REsonance 35 Hz.
6.5 G's at 39 Hz approximately .085 Disp.
- 11:05 - Started Dwell at 39 Hz.
- 11:20 - Finished Dwell
- 11:21 - CK Both TMU's all OK.

Longitudinal Shocks - 70°F

11:35 - First Shock
 11:40 - Second Shock
 11:46 - Third Shock
 11:49 - Fourth Shock
 11:54 - Fifth Shock
 11:57 - Finished longitudinal Ambient
 Transportation phase, insufficient time
 to condition and test today.
 11-28-89 08:00 - Checked TMU's both operational, have
 been in condition for 2 1/2 hours at
 +163°F ± 10°F will start test about
 9:30:00.

Verified the above statement.



Bjgoller

TMU LONGITUDINAL TRANSPORTATION TEST 163°F ± 10°

09:53 - LONGITUDINAL SINE SWEEP 163°F
 Started Sine Sweep 5-2000-5
 Resonances 33.4 Hz 71 Hz 7
 10:34 - 33.4 Hz Sine Dwell started .067 Disp.
 10:49 - Finished Sine Dwell at 33.4 Hz
 Longitudinal Sine Dwells 163°F
 10:56 - Started 71 Hz Dwell 3.2G's = .0125 Disp.
 11:11 - Started 93 Hz Dwell - 3.2G's = .0077 Disp.
 Longitudinal Shocks 163°F
 11:26 - First Shock
 11:28 - Second Shock
 11:32 - Third Shock
 11:35 - Fourth Shock
 11:39 - Fifth Shock
 11:45 - The Shroud was raised and it was
 determined that both units failed. All
 memory modules were removed for the
 purpose of examination.



Bjgoller

3.0 TEST RESULTS

The qualification testing that was conducted by Unisys on the Thiokol TMU system was not completed due to the two system failures which occurred during the testing.

The first failure occurred when TMU #0007 shutdown on November 22, 1989. The CTP-0097-D required that the TMU System run for 17 days of continuous operation. The shut down of the TMU occurred after only 14 days of operation. The cause of the shut down was low battery voltage, this was determined by the Thiokol Engineering Representative. Thiokol decided to restart the 17 day test and continue on with the testing of the TMU system.

The second failure occurred during the Longitudinal transportation testing at $160^{\circ}\text{F} \pm 10^{\circ}\text{F}$. This testing was conducted on November 28, 1989. After the testing was completed the environmental shroud was raised and both TMU units had stopped running.

The qualification testing was concluded at this point. The control and response data from all the testing conducted on the transportation monitoring units are located in appendices B through F.

3.1 ADDITIONAL TMU TESTING

Thiokol Corporation requested that some additional testing be conducted to determine the accuracy of the TMU system at a variety of temperatures.

Two tests were conducted at five different temperature levels. The tests consisted of a 10 Hz Sine Dwell at 1.5G's and a series of low level shocks. These two tests were conducted at the following temperatures: -30° , 70°F , 130°F , 140°F AND 150°F .

This additional testing was not part of the qualification testing. The only requirement for Unisys was to conduct the required tests and provide Thiokol with the control data. This test data was given to the Thiokol Engineering Representative that was present during the testing.

APPENDIX A
TRANSPORTATION MONITORING
UNIT
TEST PROCEDURE
STP - 360 - A

STP-360
Revision: A

TRANSPORTATION MONITOR UNIT
TEST PROCEDURE

Prepared By: W. R. Cooper 11/14/89
Standards Engineering

Approved By: R. C. Nybo 11/14/89
Manager Standards Engineering

The two transportation monitor units (TMU) serial number 7, qualification unit, and serial number 17, engineering control unit, shall be subjected to the following test procedures. The qualification unit shall be operated continuously for 17 days. The engineering evaluation unit can be stopped and started as directed by Thiokol personnel. During this period of operation the TMU's shall be subjected to the following sequence of testing per the following procedures. Thiokol's TRANSPORTATION MONITOR QUALIFICATION TEST PLAN, CTP-0097 REVISION C, shall be used for definition of test axes, test conditions, and test durations.

1. The MD C200 vibration system shall be set for testing of the TMU, in the horizontal axis. The test equipment shall be set up and checked out per Unisys Standard Laboratory Procedure (USLP) E-200, Sinusoidal Vibration Testing; General Procedure and USLP E-300 Shock Testing; General Procedure.
2. Install the TMU's for testing in the longitudinal axis and condition for four hours at -40 ± 10 °F.
3. Perform sine sweep test per requirements of CTP-0097C, Table II.
4. Perform sine dwell test per requirements of CTP-0097C, Table II.
5. Perform shock test per the requirements of CTP-0097C, Table II.
6. Change shock mounts and rotate TMU's to the lateral axis and recondition at cold condition for 1.5 hours for each hour or part of an hour the temperature was above -30 °F during the axes change but not longer than four hours.
7. Repeat step 3.
8. Repeat step 4.
9. Repeat step 5.
10. Change shock mounts leaving TMU's in the lateral axis and condition at 70 ± 10 °F for four hours.
11. Repeat step 3.
12. Repeat step 4.
13. Repeat step 5.
14. Change shock mounts and rotate TMU's to the longitudinal axis while maintaining the 70 ± 10 °F temperature.

15. Repeat step 3.
16. Repeat step 4.
17. Repeat step 5.
18. Change shock mounts leaving TMU's in the longitudinal axis and condition for four hours at 163 ± 10 °F.
19. Repeat step 3.
20. Repeat step 4.
21. Repeat step 5.
22. Change shock mounts and rotate TMU's to the lateral axis and recondition at hot condition for 1.5 hours for each hour or part of an hour the temperature was below 153 °F during the axes change but not longer than four hours.
23. Repeat step 3.
24. Repeat step 4.
25. Repeat step 5.
26. The MD C200 vibration system shall be set for testing of the TMU, in the vertical axis. The test equipment shall set up and checked out per Unisys Standard Laboratory Procedure (USLP) E-200, Sinusoidal Vibration Testing; General Procedure and USLP E-300 Shock Testing; General Procedure.
27. Install the TMU's with new shock mounts for testing in the vertical axis and condition for four hours at -40 ± 10 °F.
28. Repeat step 3.
29. Repeat step 4.
30. Repeat step 5.
31. Change shock mounts leaving TMU's in the vertical axis and condition at 70 ± 10 °F for four hours.
32. Repeat step 3.
33. Repeat step 4.
34. Repeat step 5.

35. Change shock mounts leaving TMU's in the vertical axis and condition for four hours at 163 +/- 10 °F.
36. Repeat step 3.
37. Repeat step 4.
38. Repeat step 5.
39. The MD C10 vibration system shall be set for testing of the TMU accelerometers, in the vertical axis. The test equipment shall set up and checked out per Unisys Standard Laboratory Procedure (USLP) E-100, Random Vibration Testing; General Procedure and USLP E-300 Shock Testing; General Procedure.
40. Mount the accelerometers so the vertical accelerometers are in the vertical axis. Condition the accelerometers and TMU's for four hours at -40 +/- 10 °F.
41. Perform the functional test sequence CTP-0097C Figure 4.
42. Change the accelerometers so the lateral accelerometers are in the vertical axis and recondition at cold condition for 1.5 hours for each hour or part of an hour the temperature was above -30 °F during the axis change but not longer than four hours.
43. Repeat step 41.
44. Change the accelerometers so the longitudinal accelerometers are in the vertical axis and recondition at cold condition for 1.5 hours for each hour or part of an hour the temperature was above -30 °F during the axis change but not longer than four hours.
45. Repeat step 41.
46. Mount the accelerometers so the vertical accelerometers are in the vertical axis. Condition the accelerometers and TMU's for four hours at 70 +/- 10 °F.
47. Perform the functional test sequence CTP-0097C Figure 4.
48. Change the accelerometers so the lateral accelerometers are in the vertical axis while maintaining 70 +/- 10 °F temperature.
49. Repeat step 47.
50. Change the accelerometers so the longitudinal accelerometers are in the vertical axis while maintaining 70 +/- 10 °F temperature.

51. Repeat step 47.
52. Mount the accelerometers so the vertical accelerometers are in the vertical axis. Condition the accelerometers and TMU's for four hours at 163 +/- 10 °F.
53. Perform the functional test sequence CTP-0097C Figure 4.
54. Change the accelerometers so the lateral accelerometers are in the vertical axis and recondition at hot condition for 1.5 hours for each hour or part of an hour the temperature was below 153 °F during the axis change but not longer than four hours.
55. Repeat step 53.
56. Change the accelerometers so the longitudinal accelerometers are in the vertical axis and recondition at hot condition for 1.5 hours for each hour or part of an hour the temperature was below 153 °F during the axis change but not longer than four hours.
57. Repeat step 53.
58. After TMU functional test data has been reduced from qualification unit serial number 7 by Thiokol as witnessed by Unisys, the following data points per CTP-0097C figure 4 shall be verified for qualification.
 - a. During quiet periods the TMU did not trigger.
 - b. During low frequency 0.2 g shocks the TMU did not trigger.
 - c. During low frequency 2.0 g shocks the TMU did trigger on each event and recorded level was within +/- 10% of the control accelerometer.
 - d. During high frequency 20.0 g shocks the TMU did not trigger.
 - e. During the 0.17 grms random vibration the TMU did not trigger.
 - f. During the 0.55 grms random vibration the TMU did trigger on each event and recorded level was within +/- 10% of the control accelerometer.
 - g. During disconnection of an accelerometer channel only one triggered event occurred.
 - h. During testing all TMU recorded temperatures were within +/-5 °F of actual test conditions.
 - i. TMU serial number 7 functioned continuously for a minimum of 17 days.

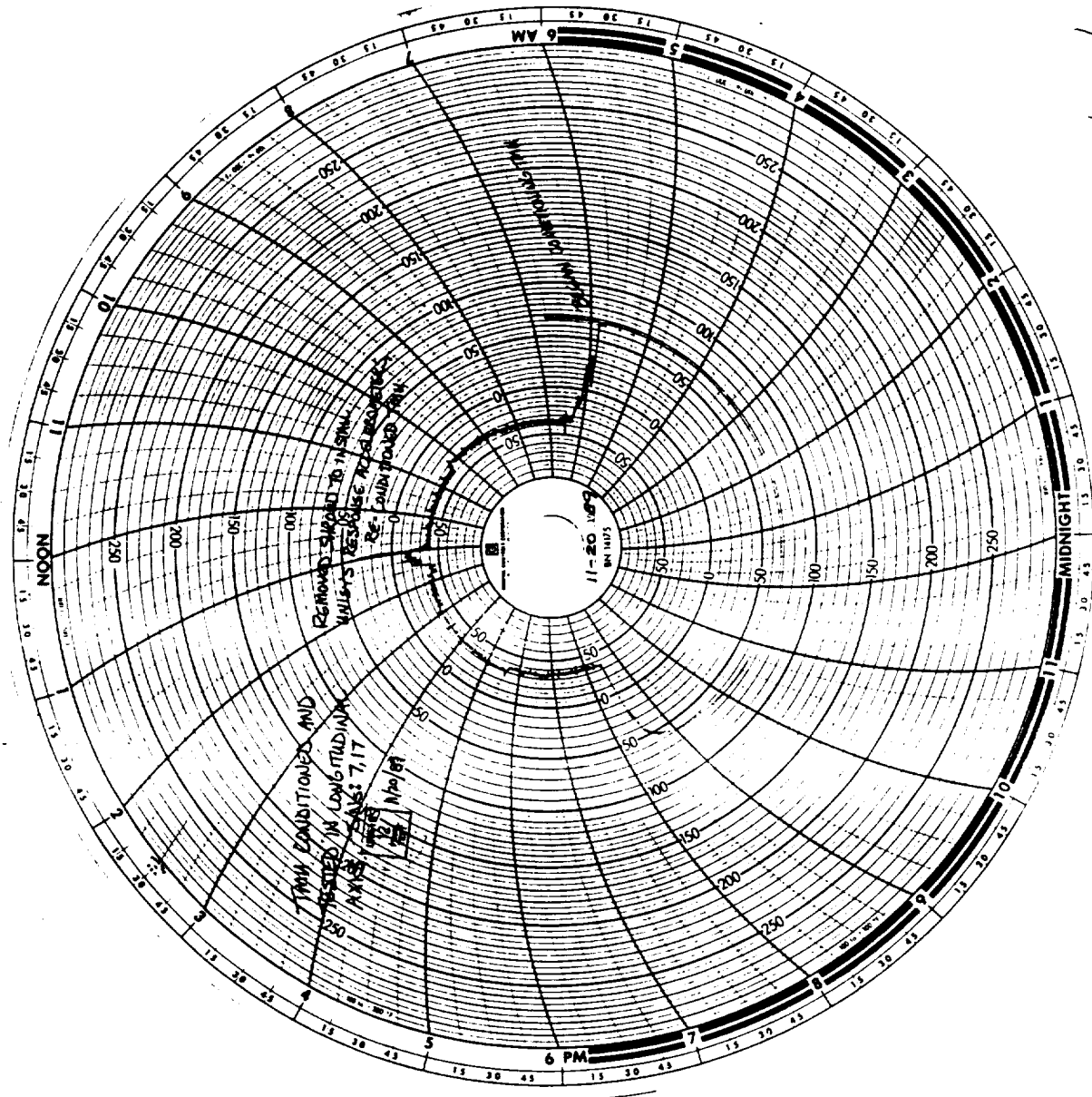
STP-360
Revision: A

REVISION RECORD

<u>REVISION</u>	<u>DESCRIPTION OF CHANGE</u>	<u>APPROVAL</u>	<u>DATE</u>
A	Changed steps 2, 27, and 40 temperatures From: -30 °F maximum to -40 °F minimum. To: -40 +/- 10 °F. Changed steps 18, 35, and 52 temperatures From: 153 °F minimum to 163 °F maximum. To: 163 +/- 10 °F.	<i>unc</i>	11/07/89

APPENDIX B
UNISYS CONTROL AND RESPONSE DATA
FROM LONGITUDINAL AXIS TRANSPORTATION
TEST ($-40^{\circ}\text{F} \pm 10^{\circ}\text{F}$)

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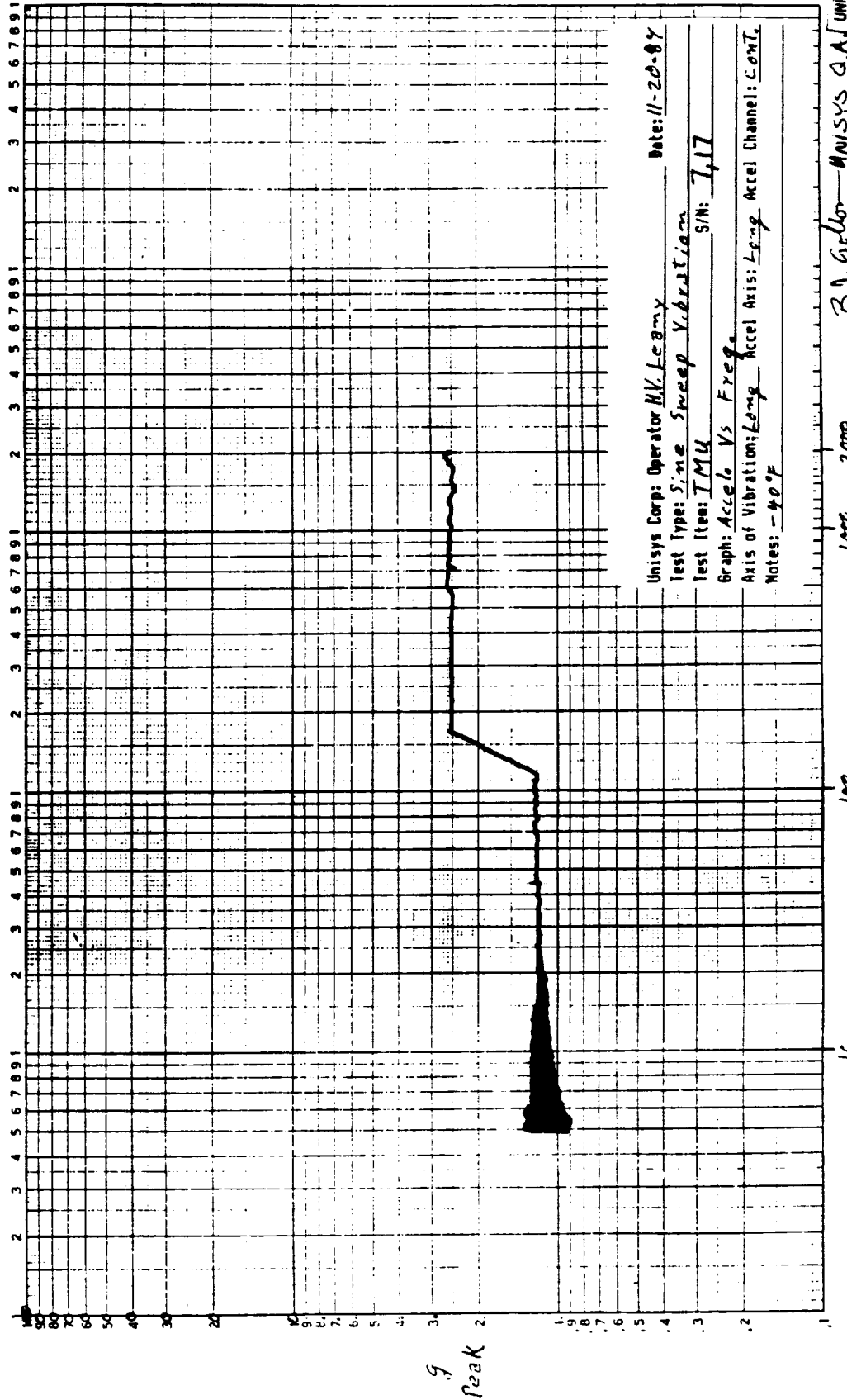


B-1

UNISYS
12
FINAL
TEST

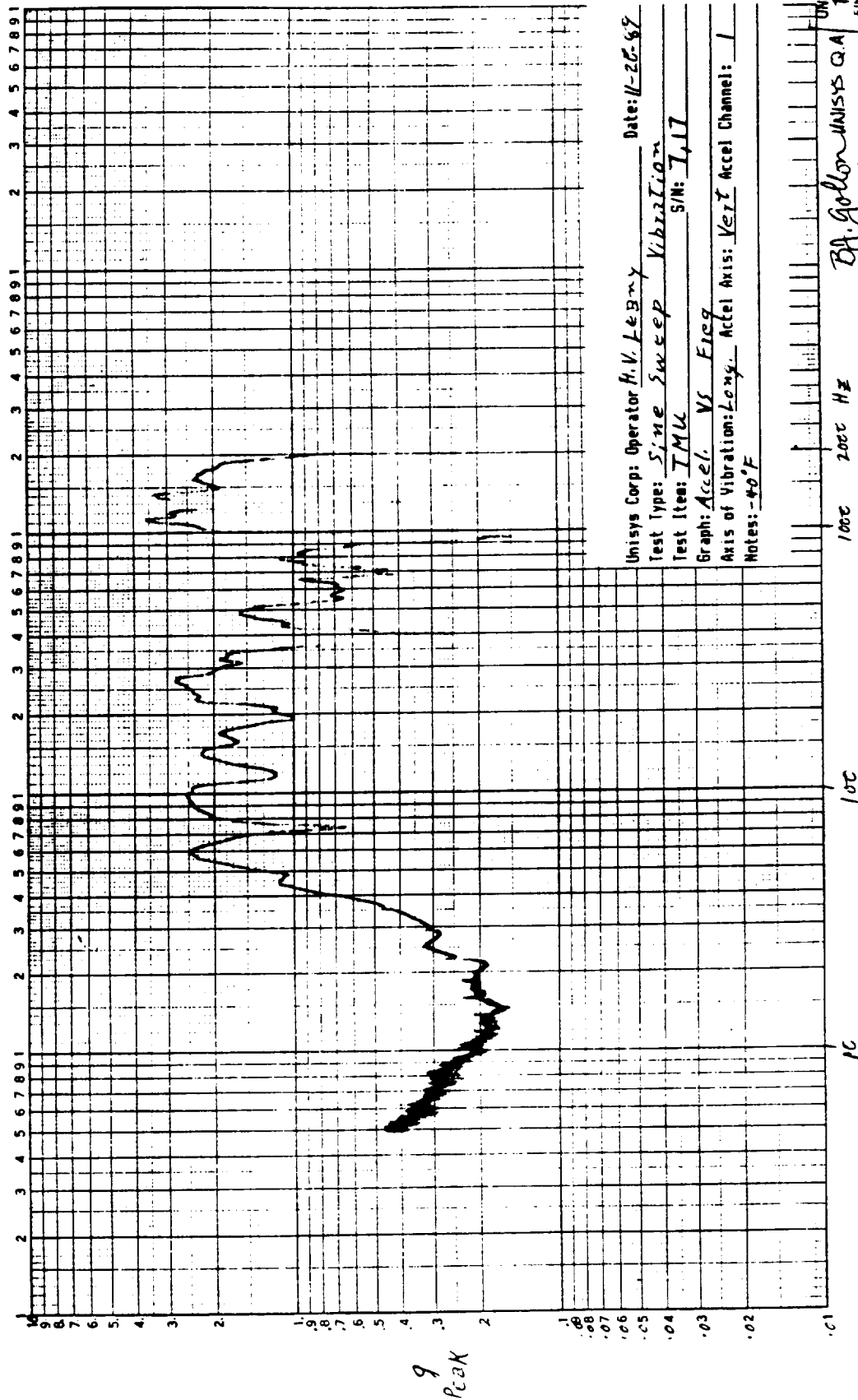
Bj. Golder UNISYS O.A.
11/21/89

Frequency Hz B-2
Dwell Input (Sweep)



Unisys Corp: Operator HV. Leamy Date: 11-20-89
 Test Type: Sine Sweep Vibration
 Test Item: IMU S/N: 7,17
 Graph: Accel Vs Freq
 Axis of Vibration: Long Accel Axis: Long Accel Channel: Cont.
 Notes: -40°F

100%
LUNNIMMIL 300-140
REINPEL MESSING CO. 3 X 3 CYCLES



Unisys Corp: Operator H.V. LeBeyec Date: 11-26-87
 Test Type: Sine Sweep Vibration
 Test Item: TMU SN: 1,117
 Graph: Accel VS Freq
 Axis of Vibration: Long. Accel Axis: Vert Accel Channel: 1
 Notes: -40°F

UNISYS
12
FINAL
TEST

Bj. Gollon UNISYS QA
11/21/89

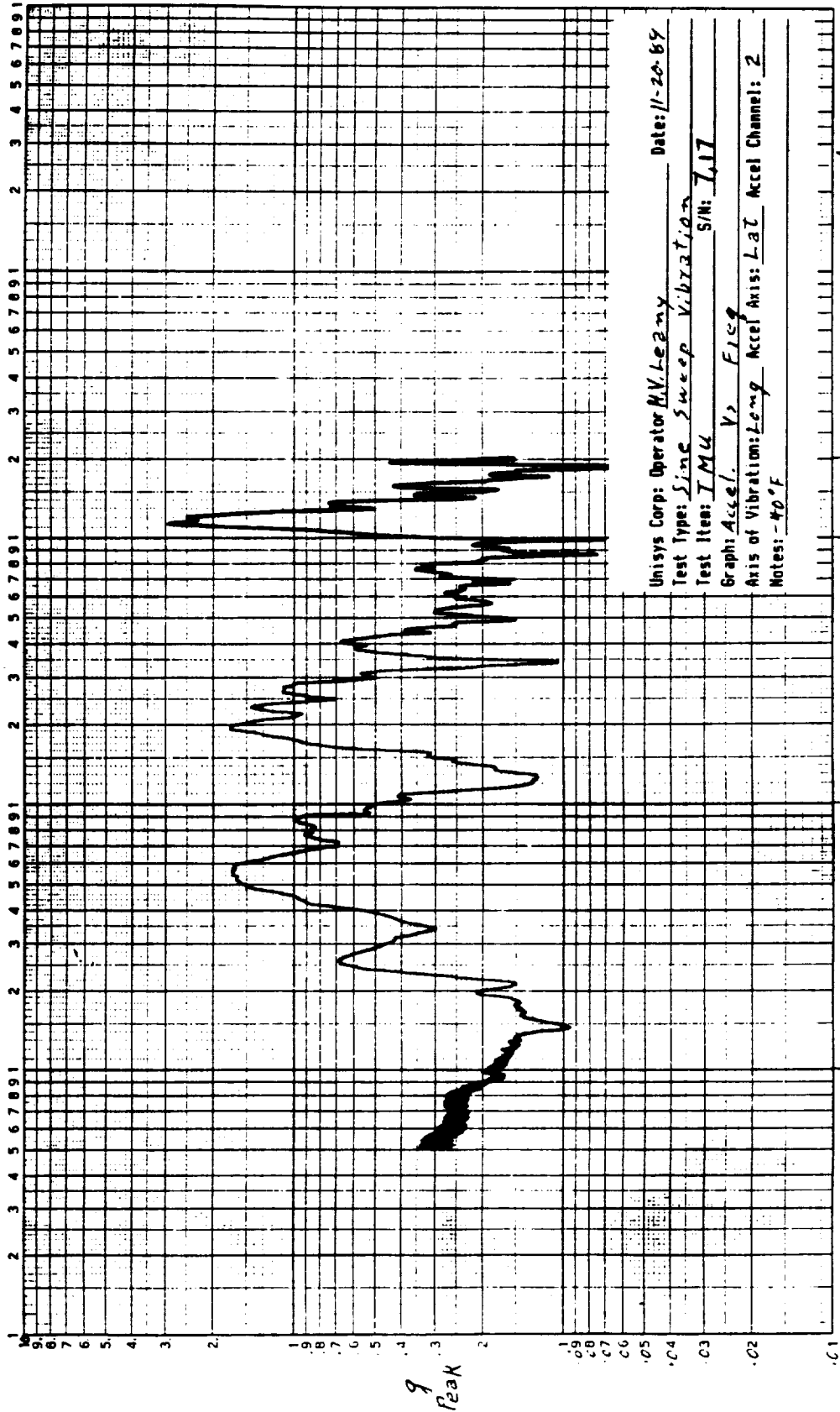
Frequency

Dwell Response B-3 (Sweep)

1102 LOGARITHMIC 330-143
KEUFFEL & ESSER CO. J.A.S. CYCLES

CH 1

UNISYS MIL 350-140
KEUFFEL & ESSER CO. MOUNTAIN VIEW, N.J.
JAN 5 CYCLES



B.J. Golder Unisys Co.
11/21/69

B-4
Dwell Response (Sweep)

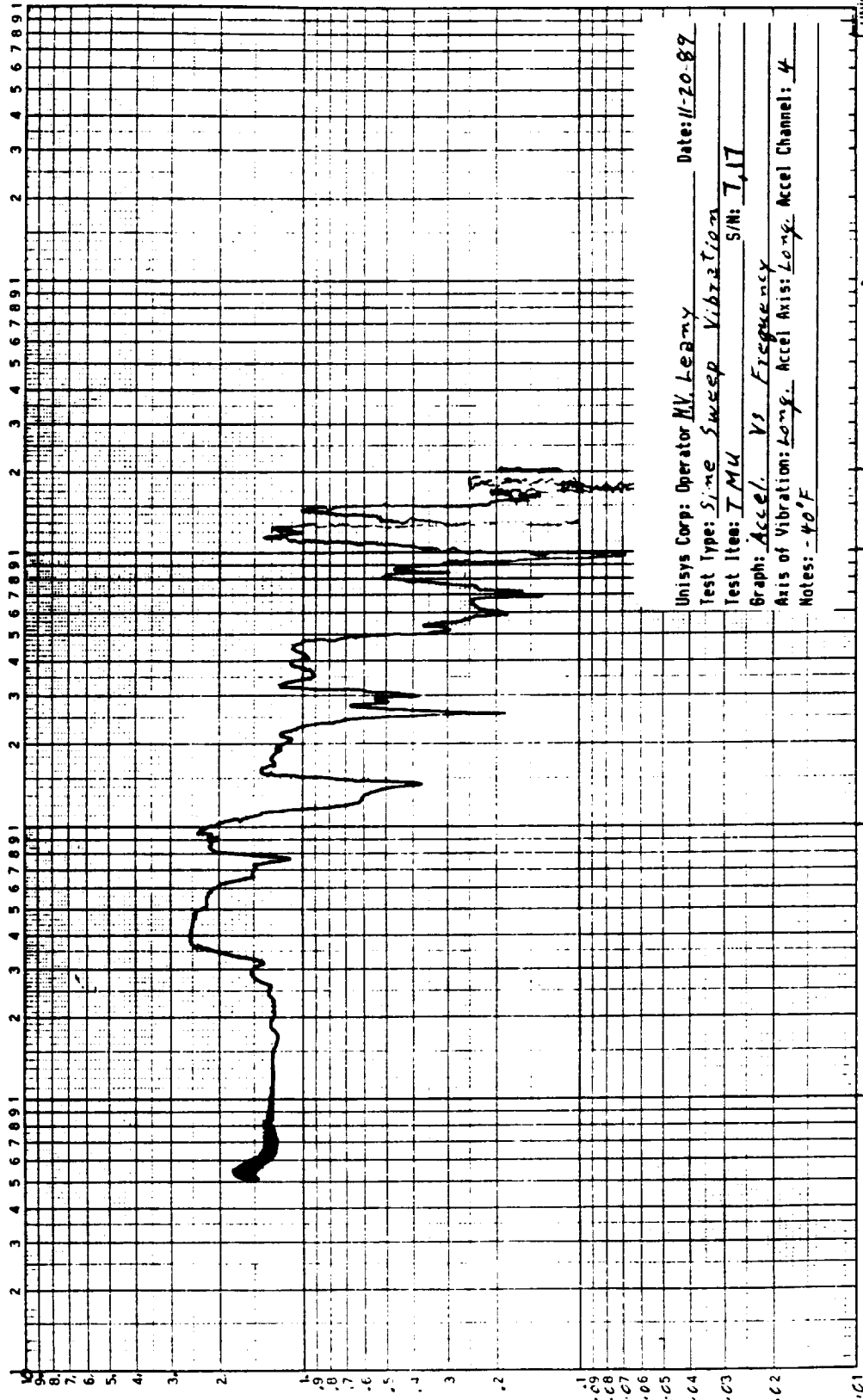
UNISYS
12
FINAL
TEST

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LOGARITHMIC 300-120
NEUFEL & SERRA CO. 11/1/89
3 X 3 CYCLES

) CH



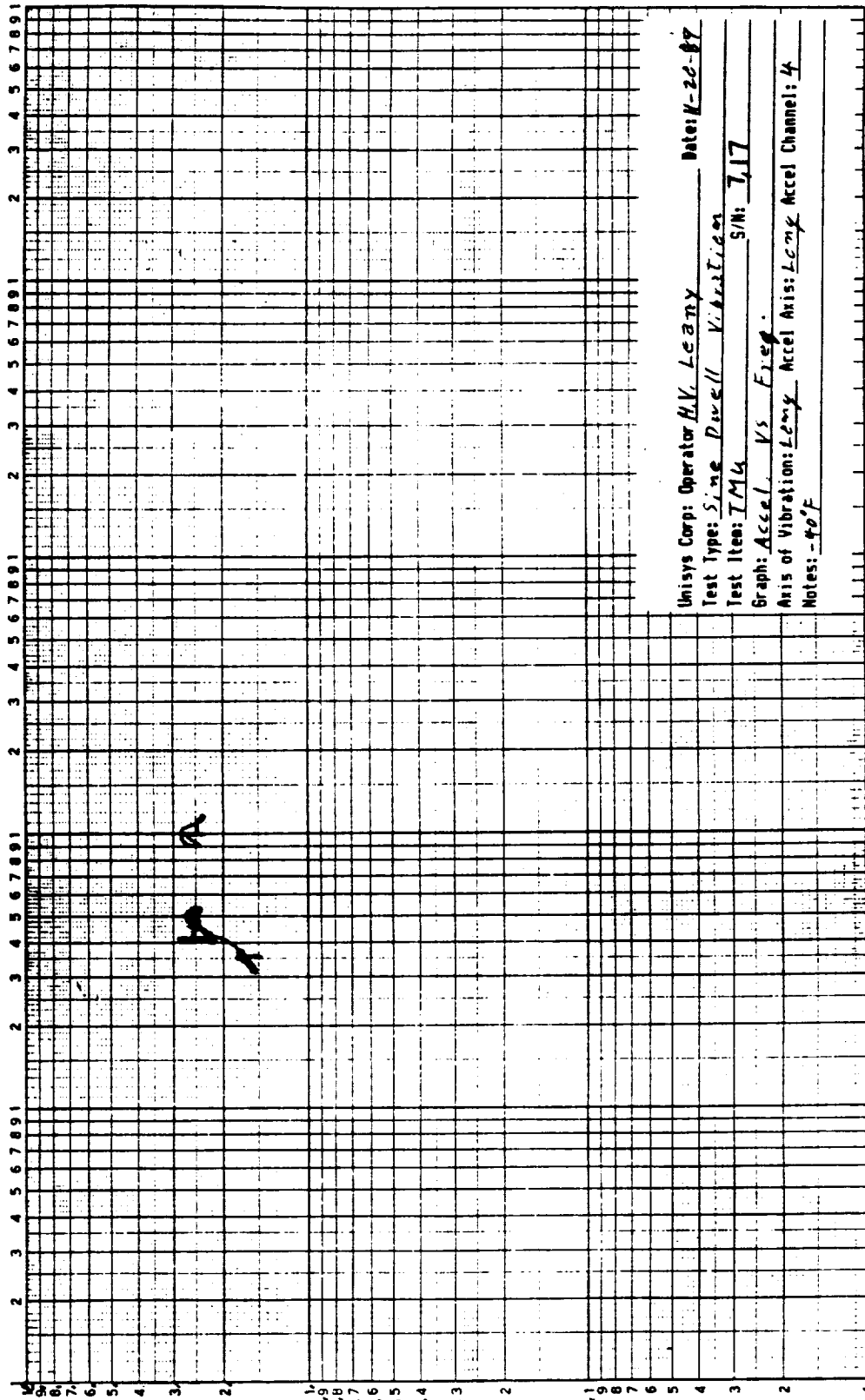
Unisis Corp: Operator MV. Leamy Date: 11-20-87
Test Type: Sine Sweep Vibration
Test Item: IMU S/N: 7,17
Graph: Accel. VS Frequency
Axis of Vibration: Long. Accel Axis: Long. Accel Channel: 4
Notes: -40°F

UNISIS
12
FINAL
TEST

B.J. Goller UNISIS Q.A.
11/21/89

Frequency Hz B-5
Dwell Response (Sweep)

LOGAN INMIL 358-145
NEUPPEL STEEL CO. 311-1111
3 A 3 CYCLES



Unisys Corp: Operator H.V. Leany Date: 11-20-87
 Test Type: Sine Dwell Vibration
 Test Item: TM4 S/N: 717
 Graph: Accel. vs Freq.
 Axis of Vibration: Long Accel Channel: 4
 Notes: -40°F

UNISYS
12
FINAL
TEST

Bj. Goller-Unisys Q.A.
11/24/87

1000

100

10

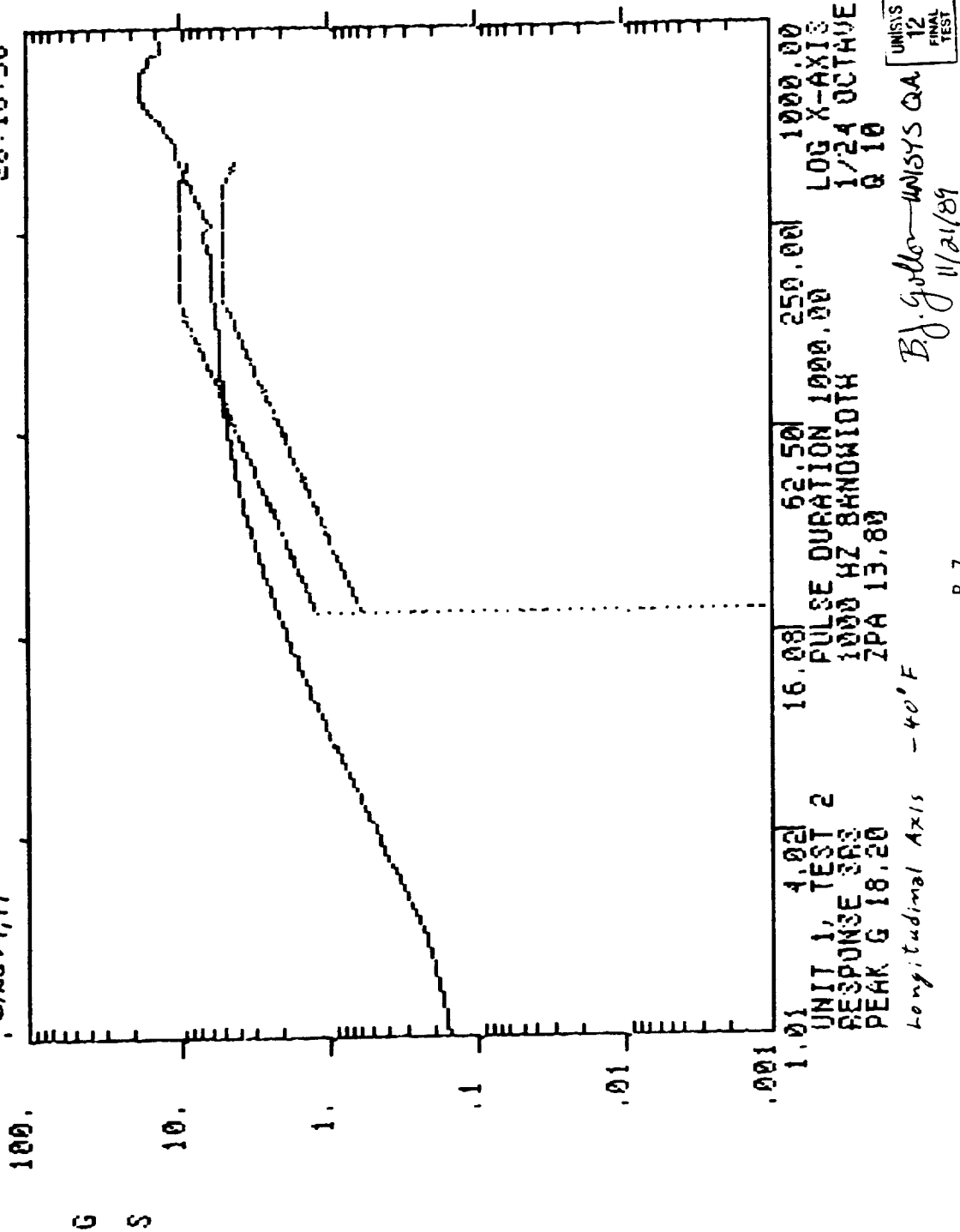
Frequency Hz

B-6

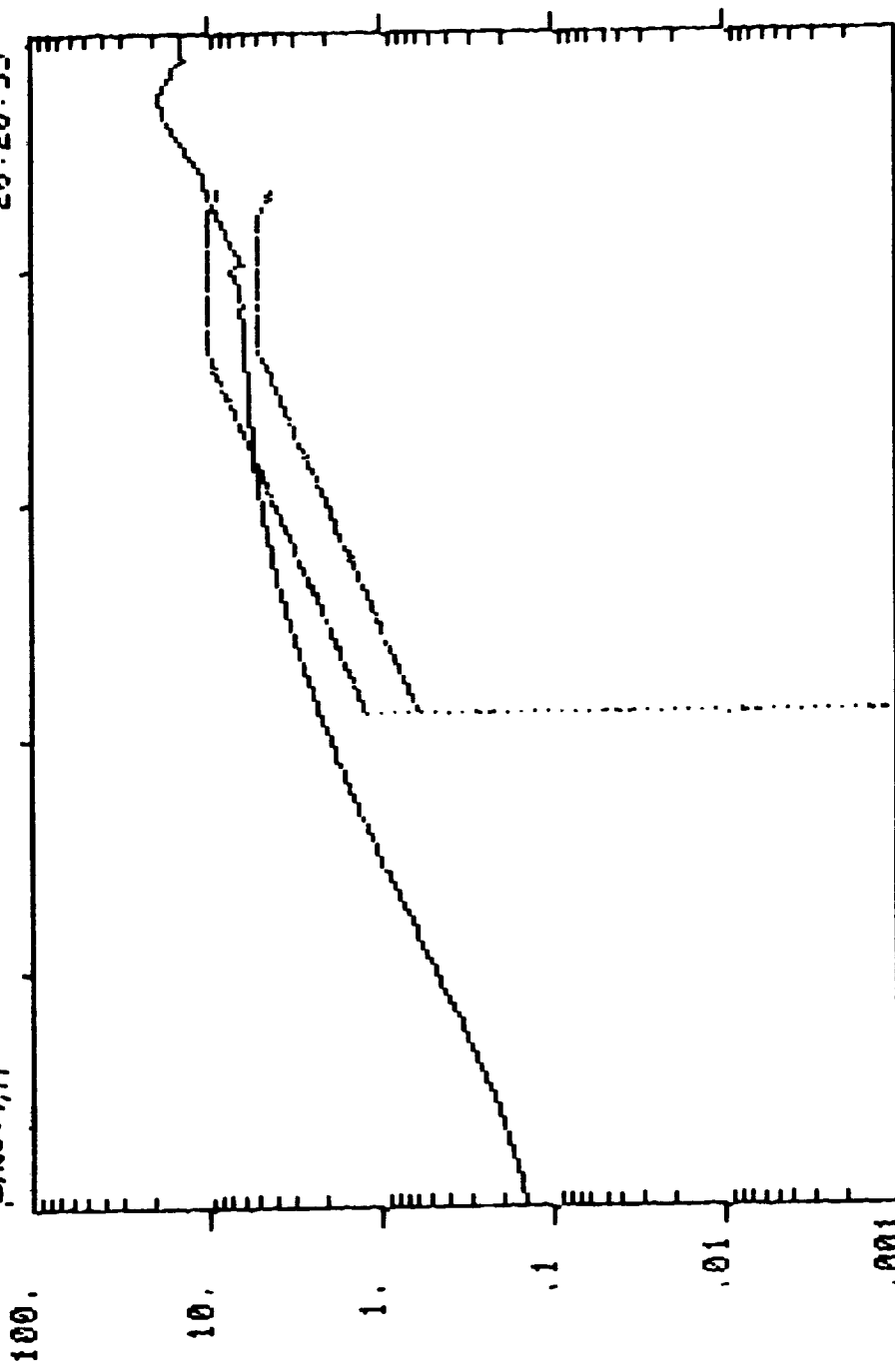
Sine Dwell

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THIOL 3RM TMU QUALIFICATION COMPOSITE MAXI MAX 20-NOV-89
S/Ns: 7,17 20:16:38



THIOKOL SRM THU QUALIFICATION COMPOSITE MAXI MAX 20-NOV-89
 S/Ns: 7,17 20:20:53



1.01 4.02 16.08 62.50 250.00 1000.00
 UNIT 1, TEST 2 LOG X-AXIS
 RESPONSE 3R3 PULSE DURATION 1000.00
 PEAK G 18.41 1000 HZ BANDWIDTH
 ZPA 13.96 1/24 OCTAVE
 Q 10
 Longitudinal Axis -40°F

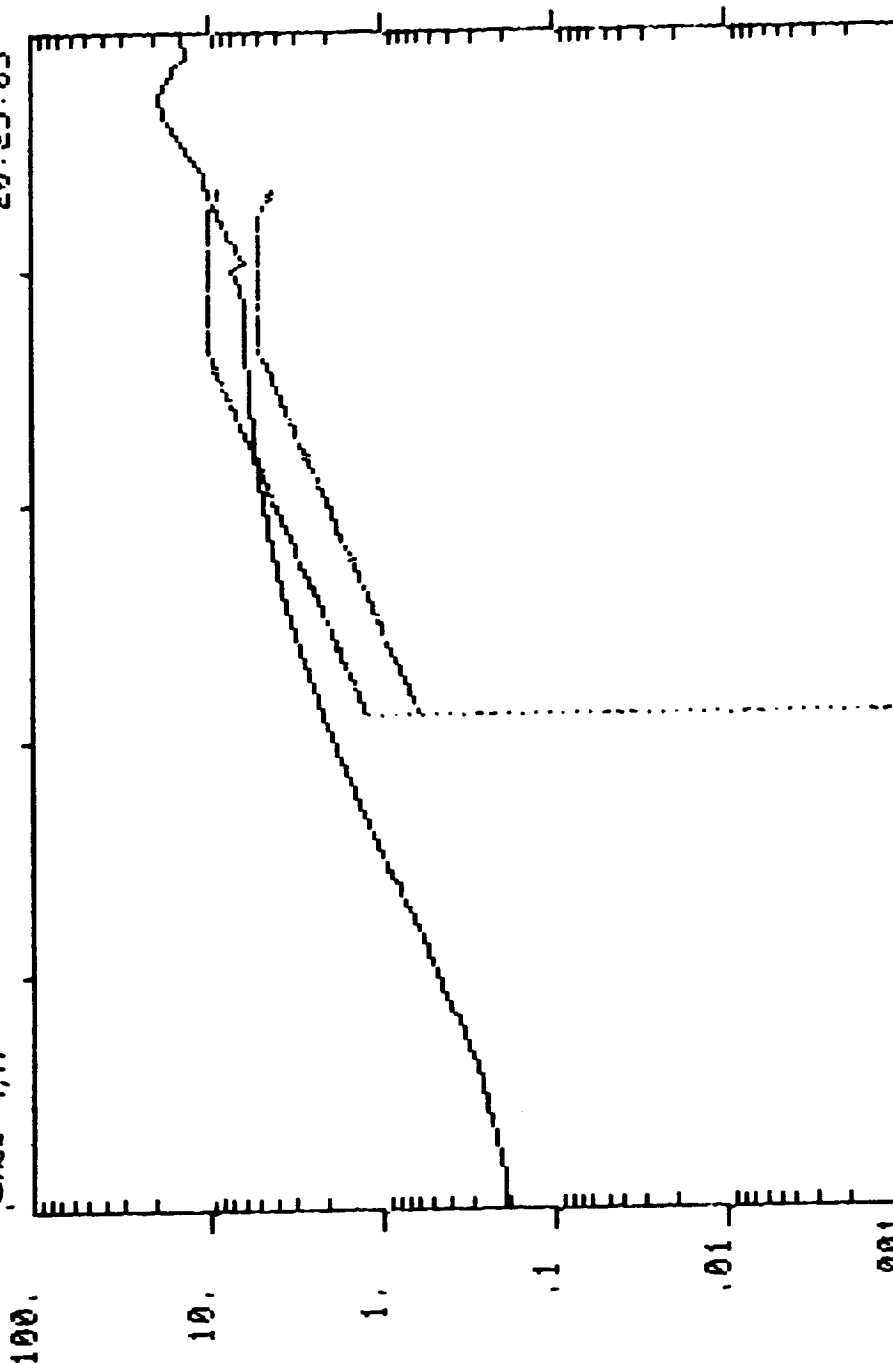
UNISTG
 17
 FINAL
 TEST

Golden UNISYS QA.
 11/21/89

B-8

Shack #2

THIOL SRM THU QUALIFICATION COMPOSITE MAXI MAX 20-NOV-89
 S/N: 7,17 20:25:03



1.01 4.02 16.08 62.50 250.00 1000.00
 UNIT 1, TEST 2 PULSE DURATION 1000.00 LOG X-AXIS
 RESPONSE 3R3 1000 HZ BANDWIDTH 1/24 OCTAVE
 PEAK G 18.41 ZPA 13.96 Q 10

UNISYS
 12
 FINAL
 TEST

Bj. Gollon UNISYS Q.A.
 11/21/89

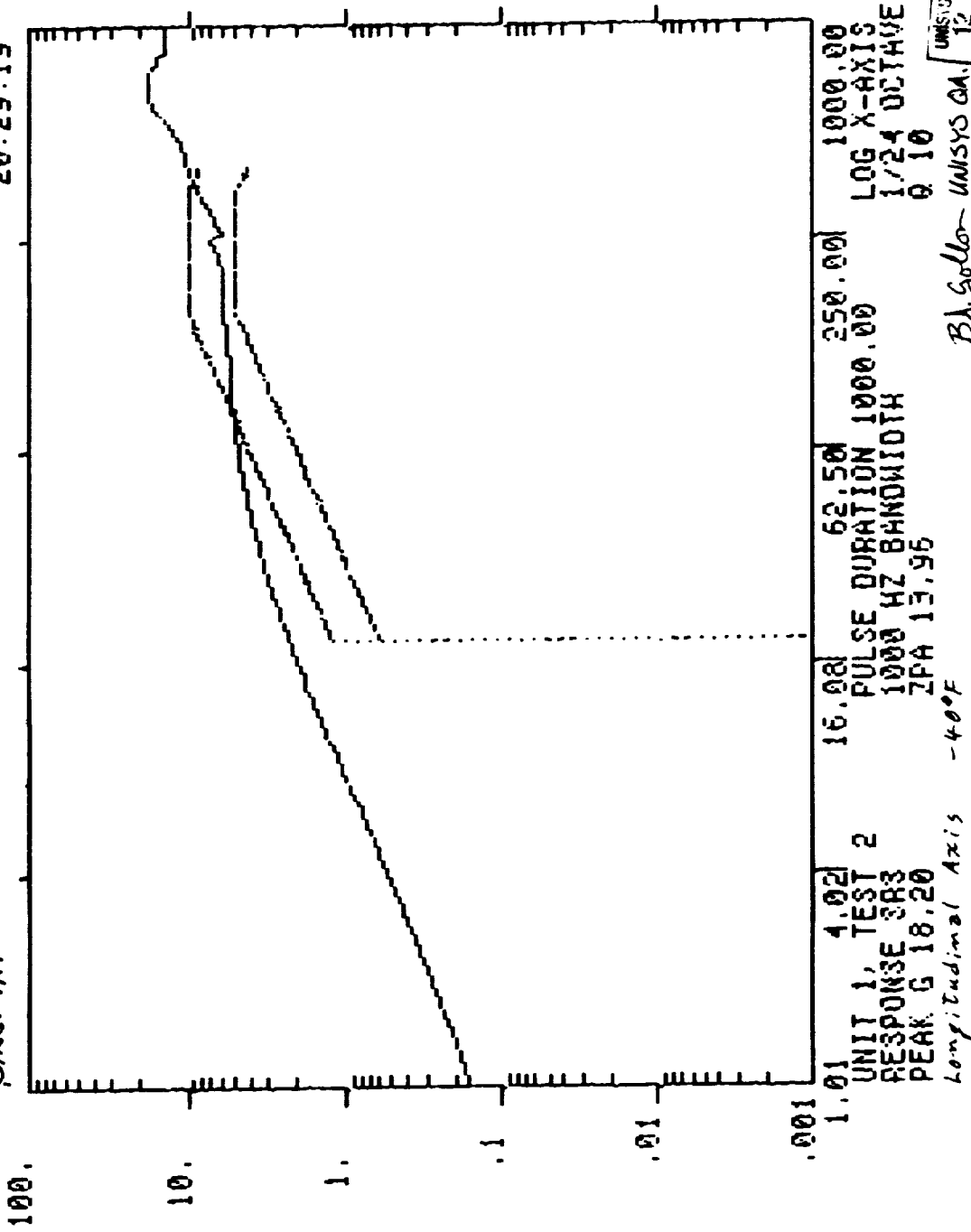
-40°F

Longitudinal Axis

B-9

Shack #3

THICKOL SRM THU QUALIFICATION COMPOSITE MAXI MAX 20-NOV-69
 S/Ns: 7,17 20:29:19



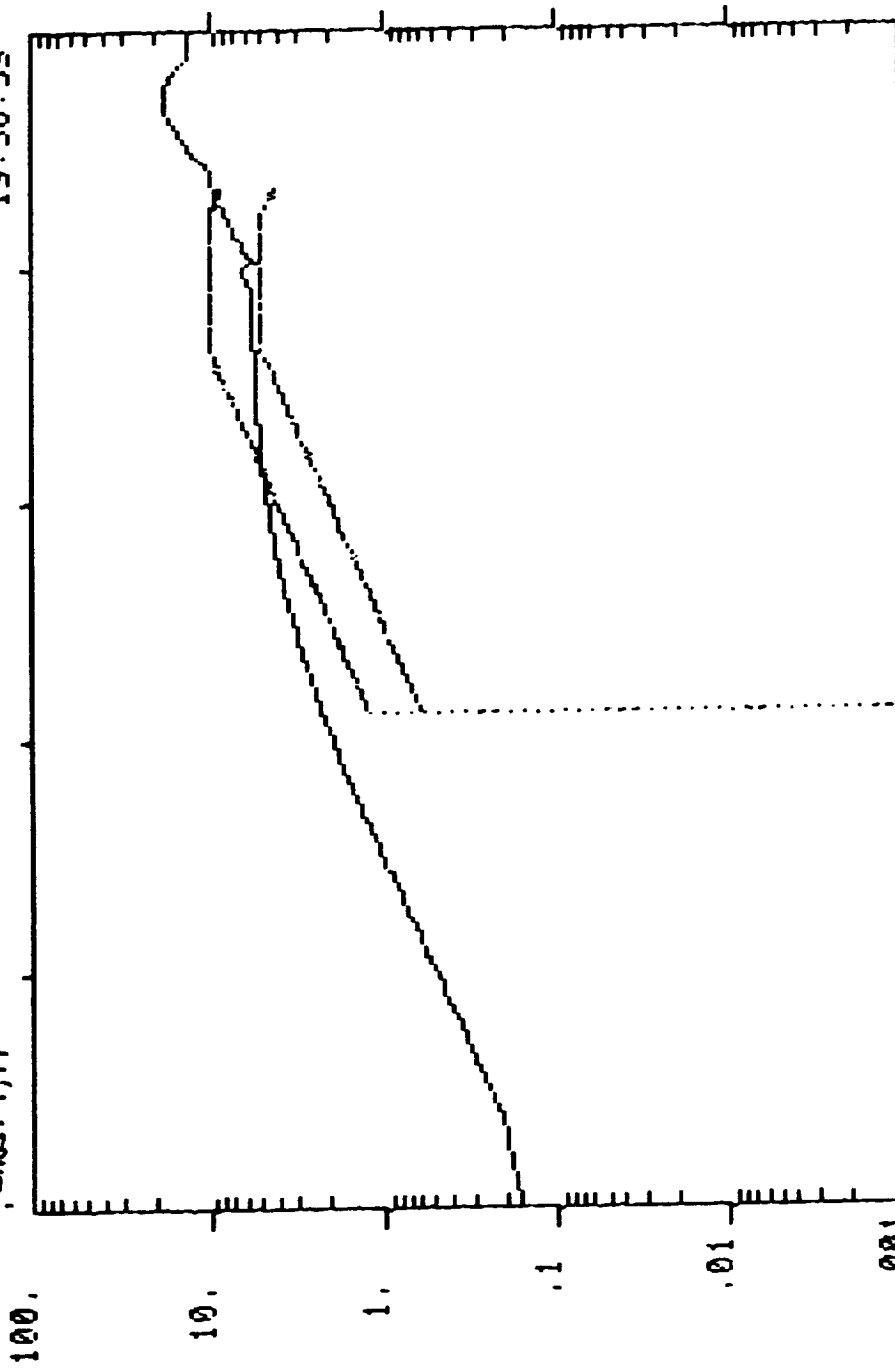
1.01 4.021 16.081 62.50 250.00 1000.00
 UNIT 1, TEST 2 PULSE DURATION 1000.00 LOG X-AXIS
 RESPONSE 3R3 1000 HZ BANDWIDTH 1/24 OCTAVE
 PEAK G 18.20 ZPA 13.96 0.10

UNISYS
 12
 FINAL
 TEST
 B. J. Goller - UNISYS QA.
 11/21/69

B-10

Shock # 4

THIOL SRM TMJ QUALIFICATION COMPOSITE MAXI MAX 20-NOV-89
 SAs: 7,17 19:38:39



1.01 4.02 16.08 62.50 250.00 1000.00
 UNIT 1, TEST 2 PULSE DURATION 1000.00 LOG X-AXIS
 RESPONSE 3PS 1000 HZ BANDWIDTH 1/24 OCTAVE
 PEAK G 17.99 ZPA 13.49 Q 10

UNISYS
 12
 11/21/89

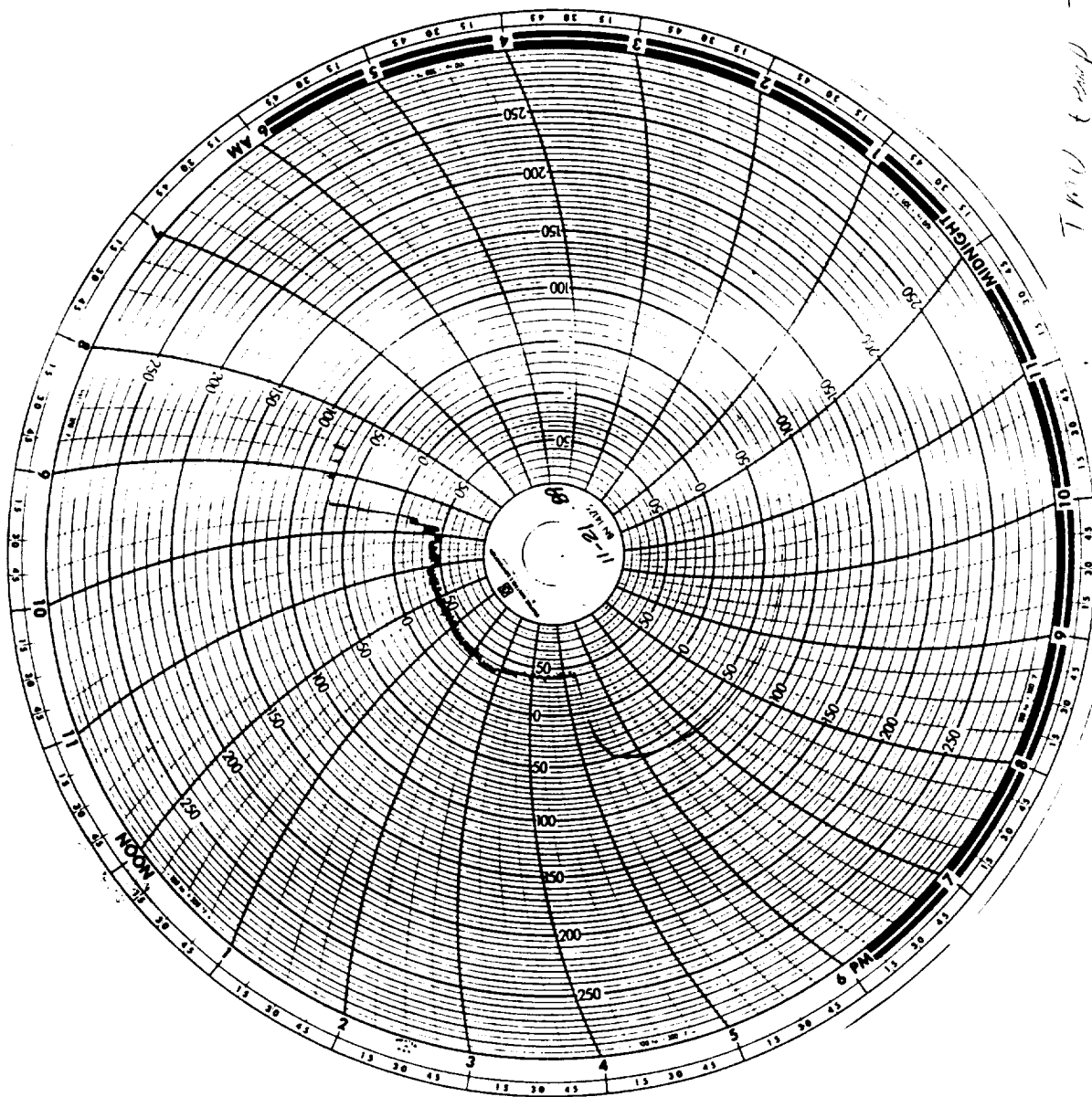
Longitudinal Axis -40°F
 B-11

~~Shoch~~ Shoch #5

APPENDIX C
UNISYS CONTROL AND RESPONSE DATA FROM
TANGENTIAL AXIS TRANSPORTATION TEST
(-40°F ± 10°F)

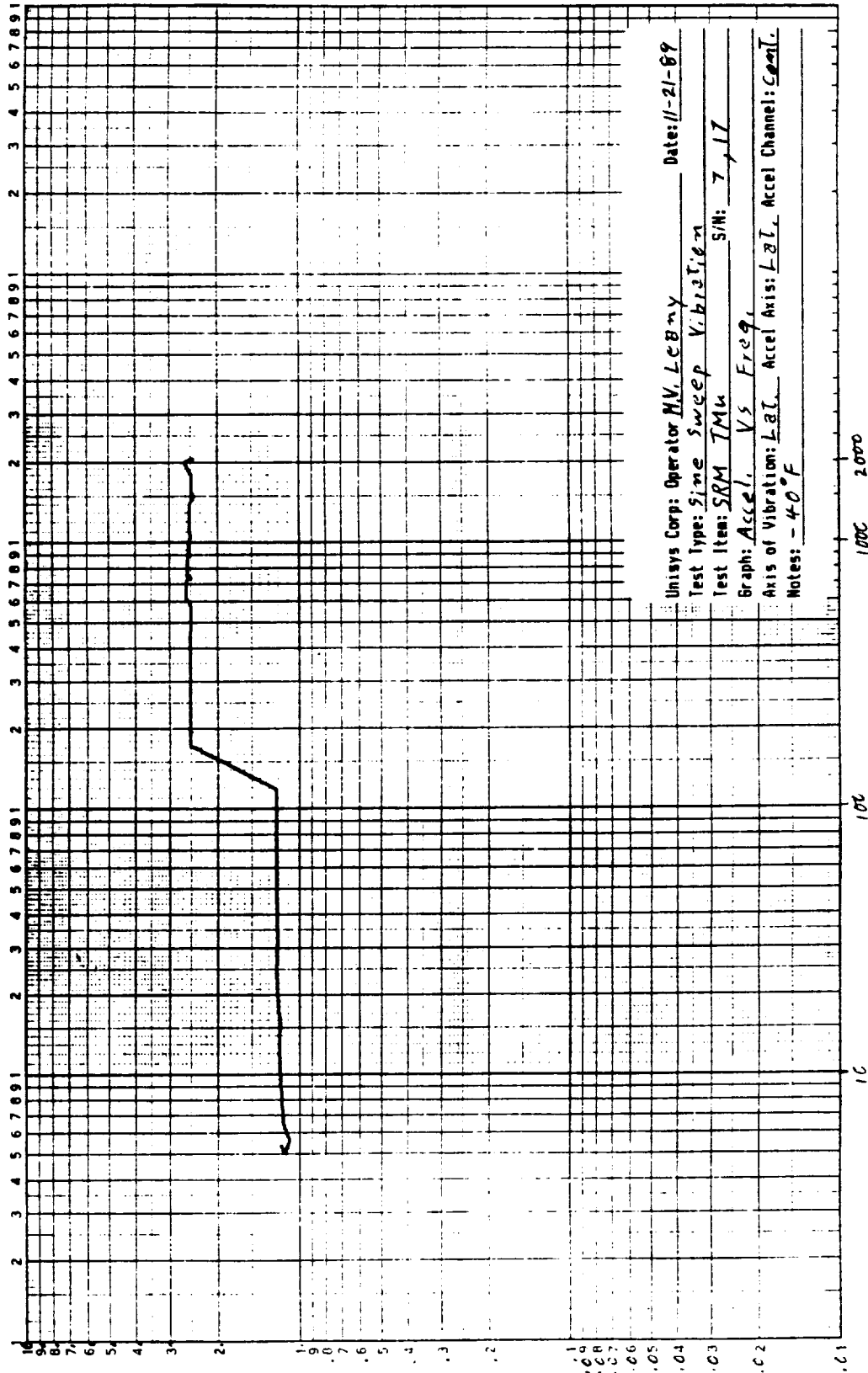
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Temp -40°F



ORIGINAL PAGE IS
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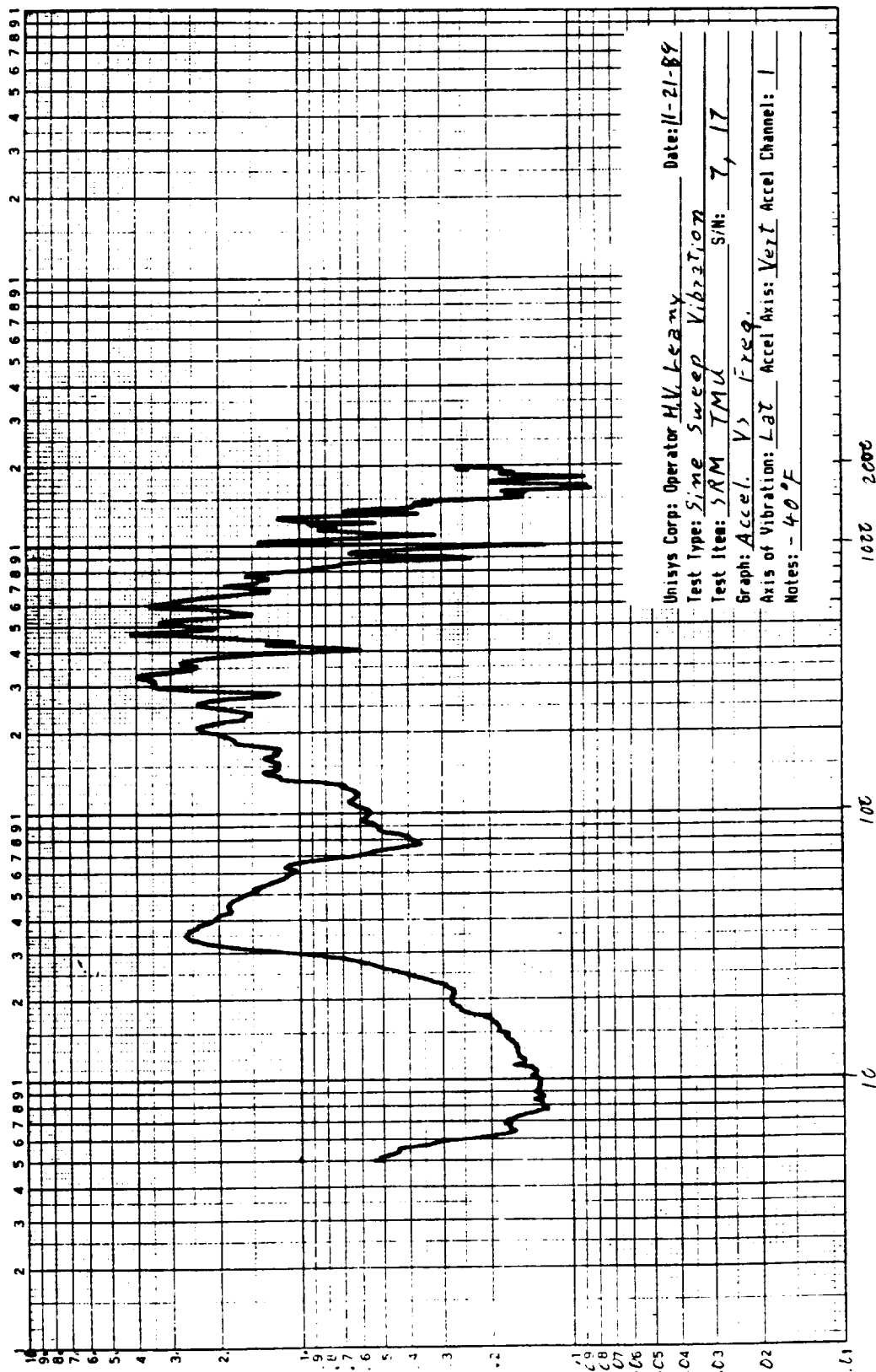
LOGAN THOMAS 330-1423
KEUFFEL & ESSER CO. 100 YEARS
3.5 CYCLES



Frequency Hz C-2
Sine Sweep Input

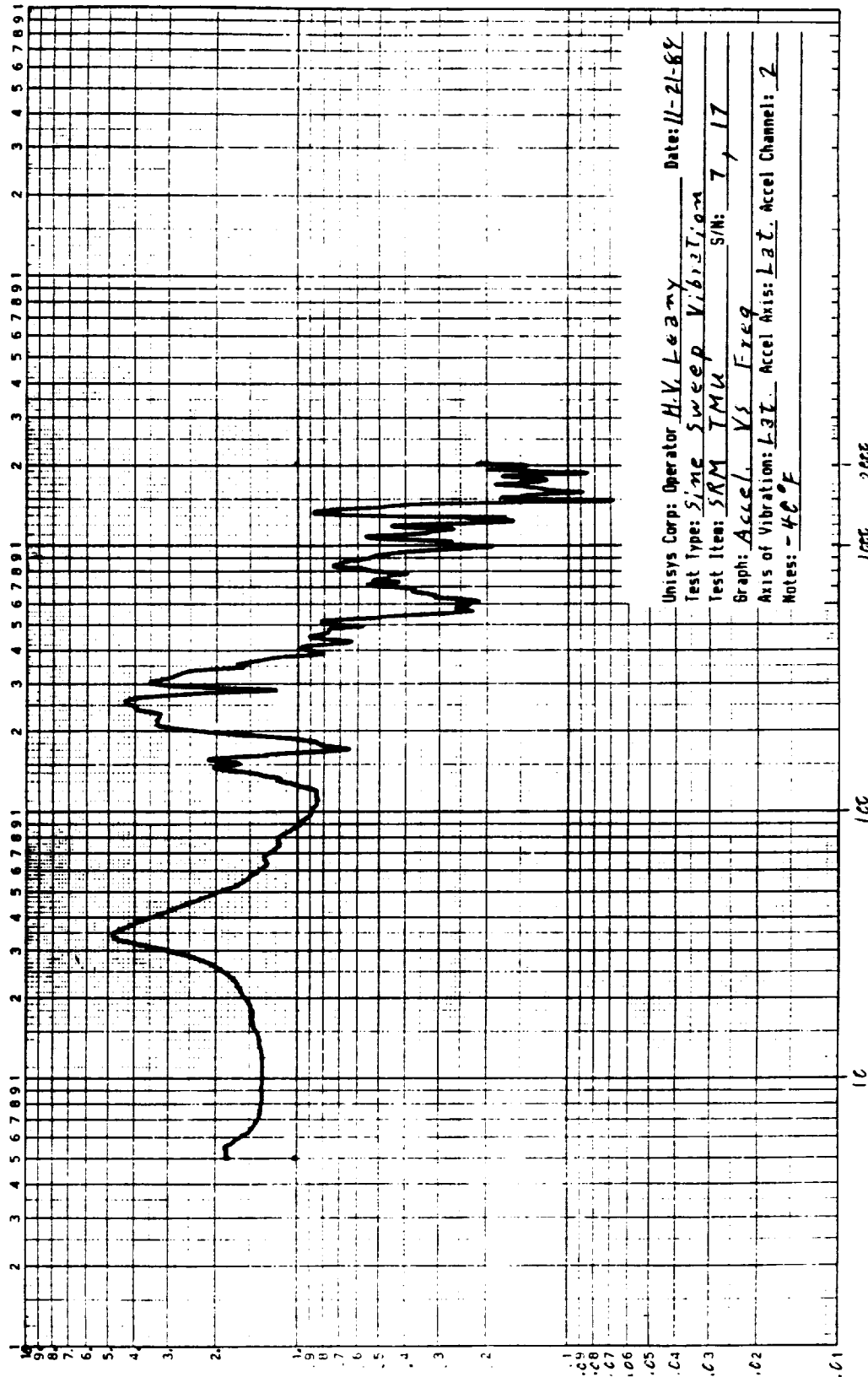
LOGANITHMIL 300-120
KEUFFEL & ESSER CO. 100-120
3 X 5 CYCLES

ORIGINAL PAGE 13
OF POOR QUALITY



Frequency Hz
Sine Sweep Response
C-3

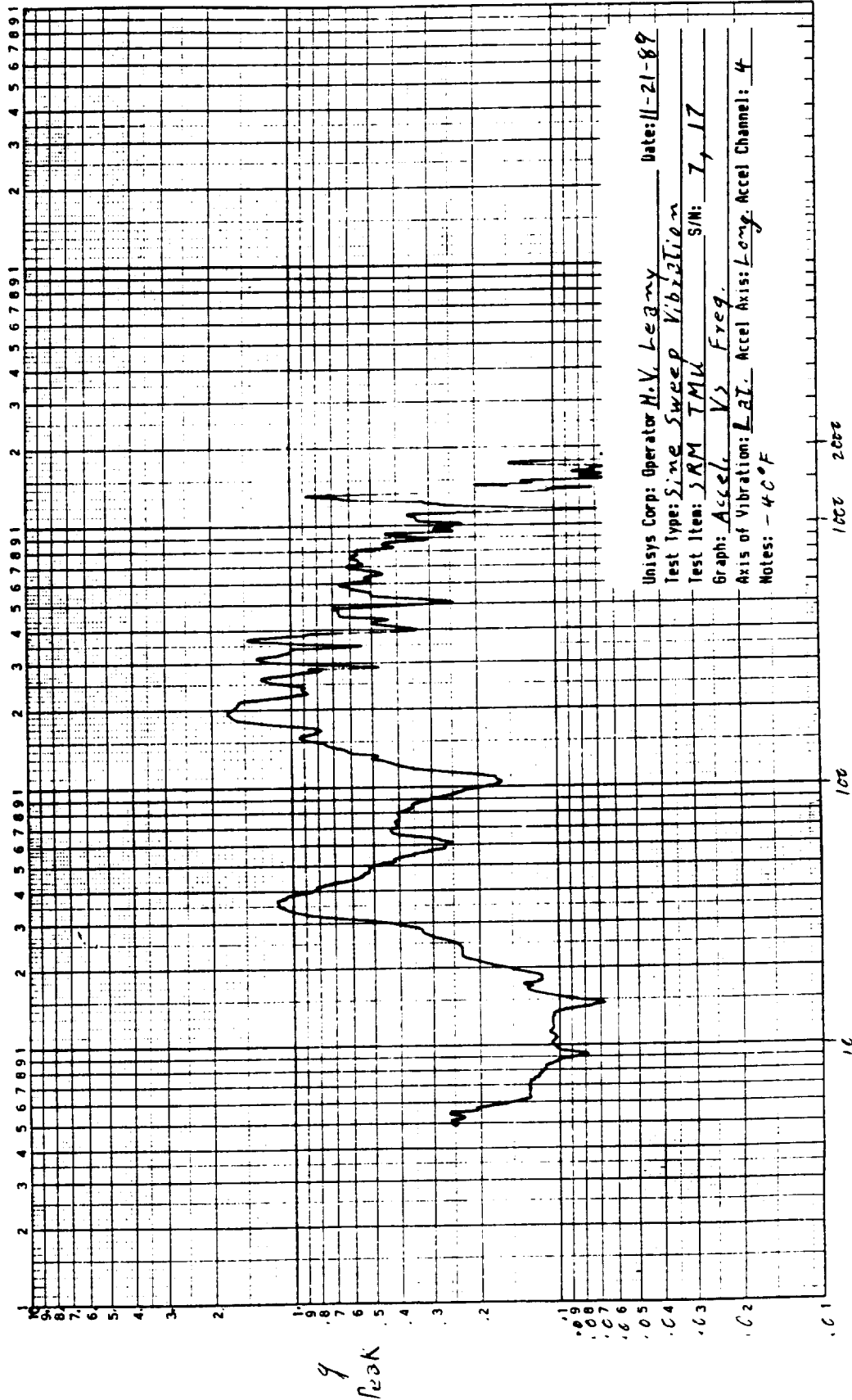
1502 LOGANIMMIL 300-143
REUFFEL BESSER CO. MINN. 111
JAN 5 CYCLES



Unisys Corp: Operator H.V. Leary Date: 11-21-88
Test Type: Sine Sweep Vibration
Test Item: SRM TMU S/N: 7, 17
Graph: Accel. Vs. Freq
Axis of Vibration: L-Z Accel Axis: L-Z Accel Channel: 2
Notes: -40°F

Frequency Hz
Sine Sweep
C-4 Response

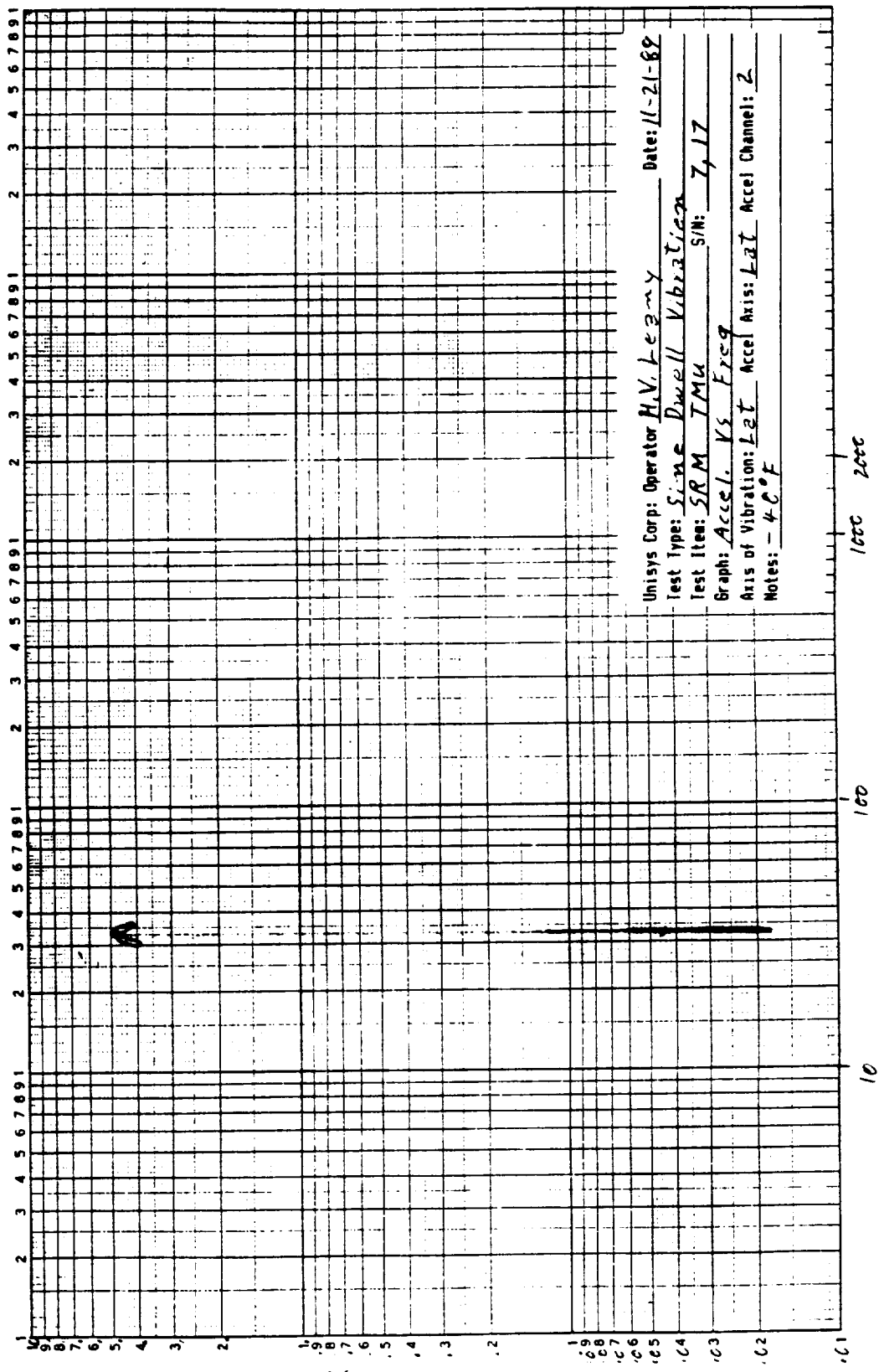
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OF POOR QUALITY



C-5
Sine Sweep Response

ORIGINAL PAGE IS
OF POOR QUALITY

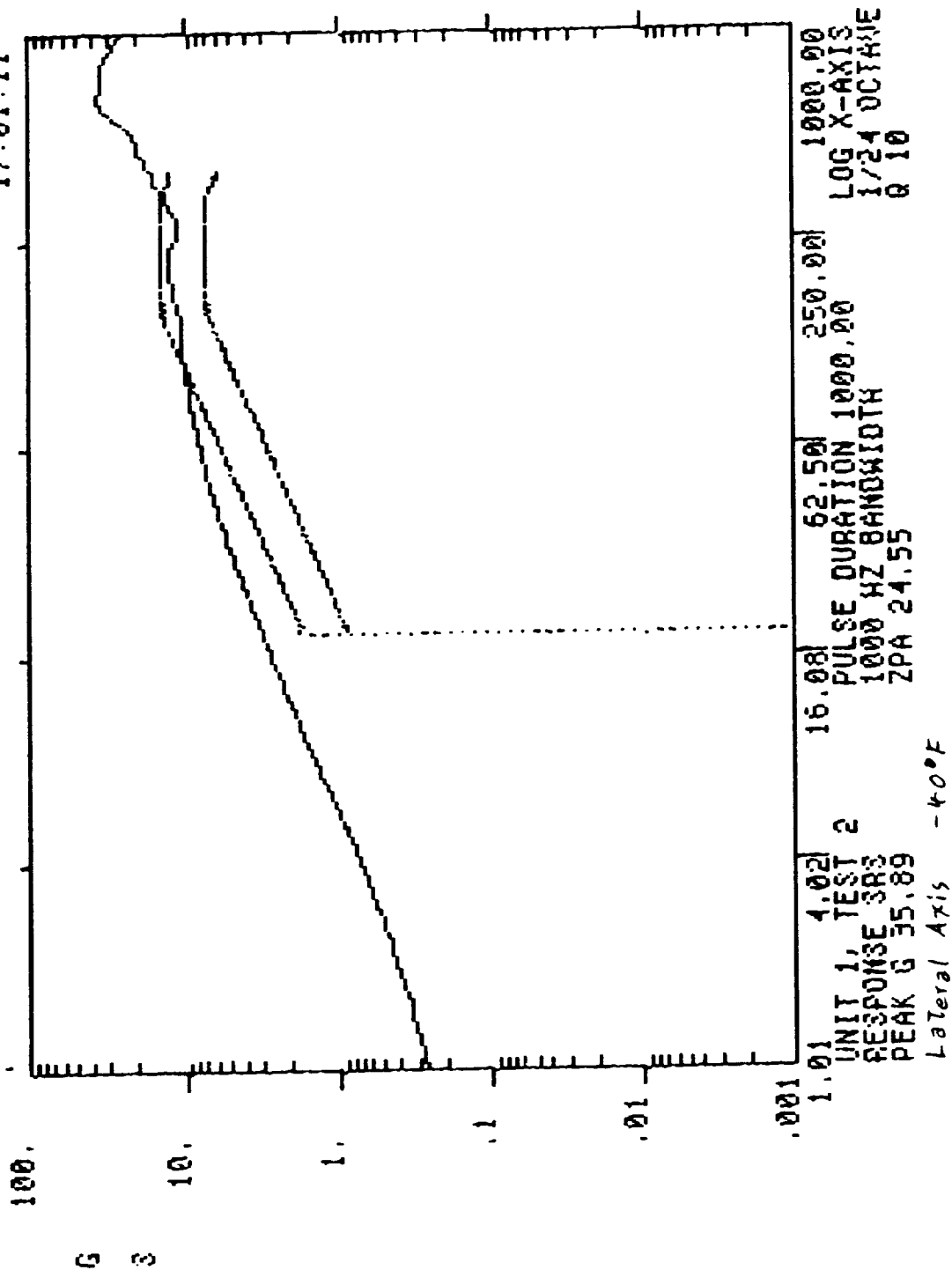
LOGAN TITMIL 358-143
NEUTPFL & ESSER CO. 1001 N. 1st
3 X 3 CYCLES



Unisys Corp: Operator H.V. Leary Date: 11-21-89
Test Type: Sine Dwell Vibration
Test Item: SRM TMU S/N: 7, 17
Graph: Accel. Vs Freq
Axis of Vibration: Lat Accel Axis: Lat Accel Channel: 2
Notes: -40°F

Frequency Hz C-6
Sine Sweep Response

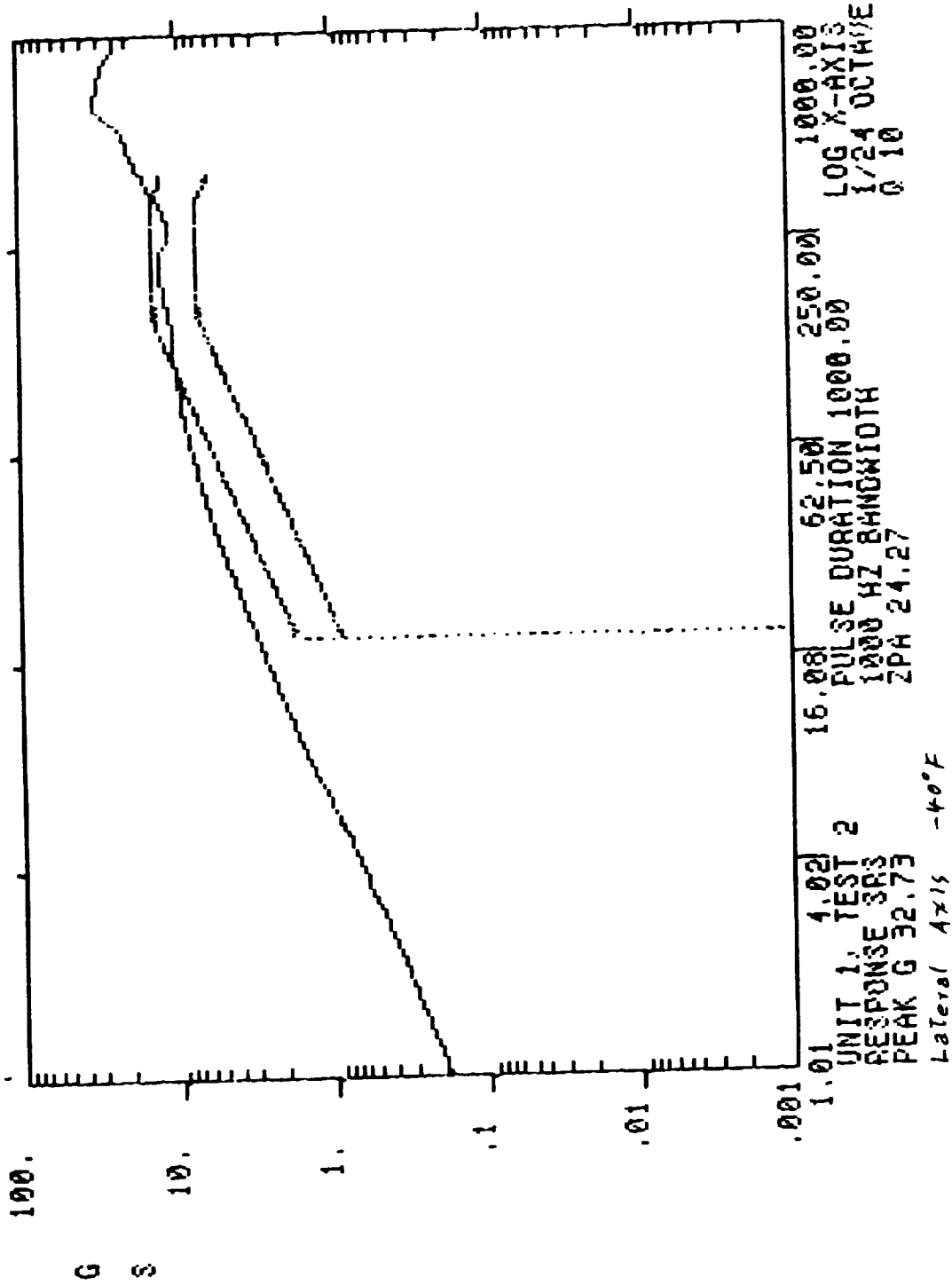
THICKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 21-NOV-89
17:01:11



C-7

Stick #1

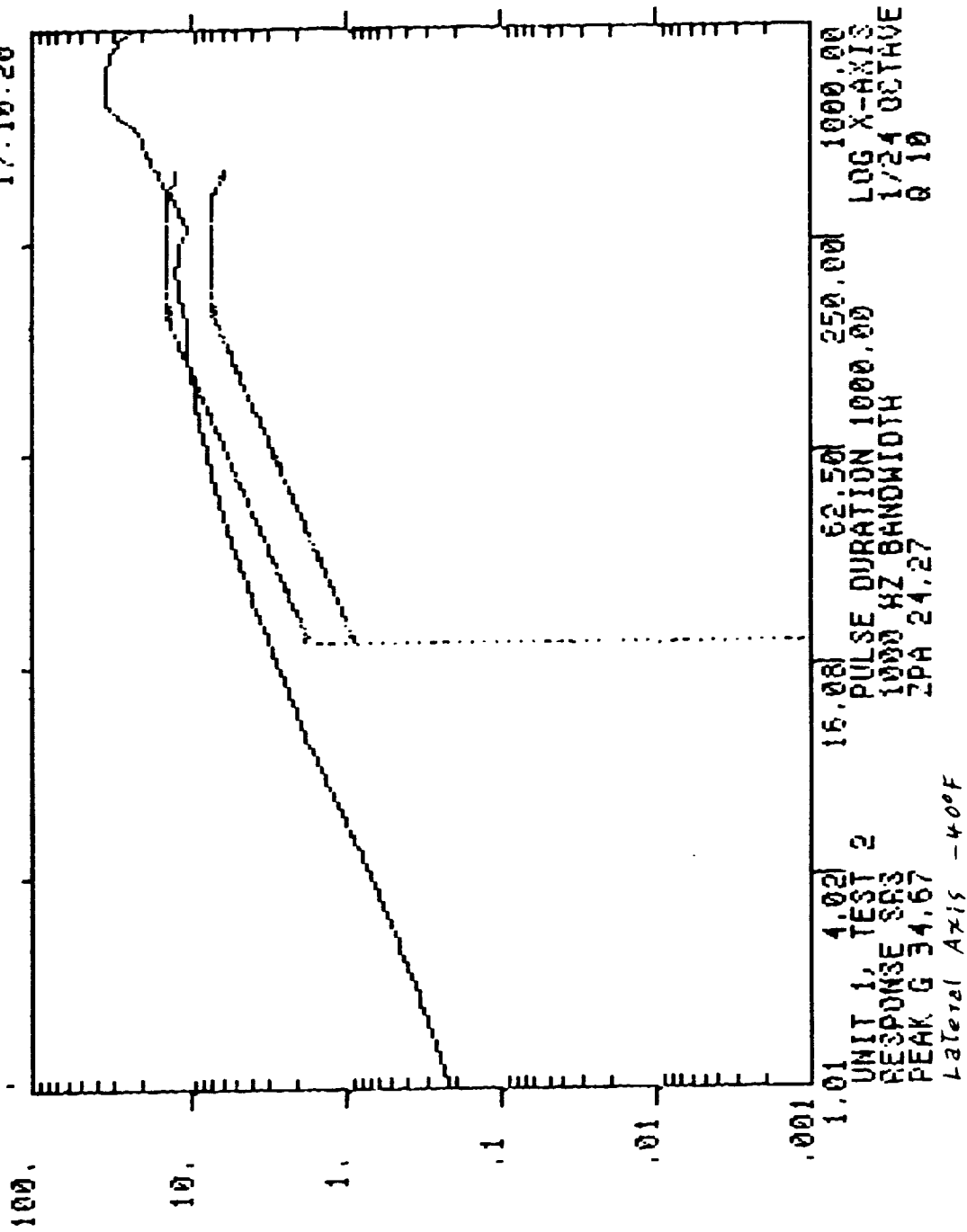
THIOL SRH TMU QUALIFICATION COMPOSITE MAXI MAX 21-NOV-89 17:05:45



C-8

Shock #2

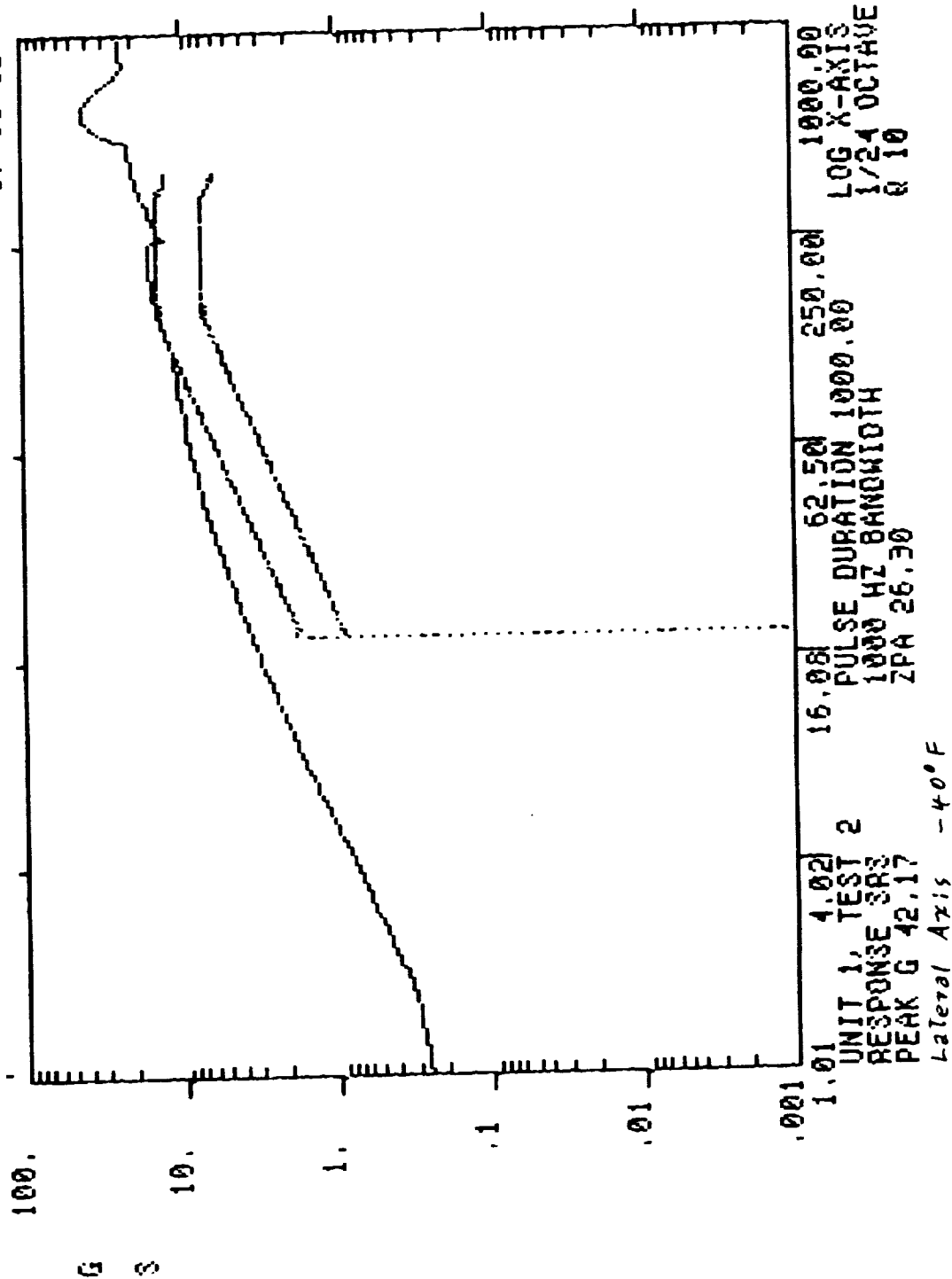
THICKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 21-NOV-89 17:10:20



C-9

Stock #3

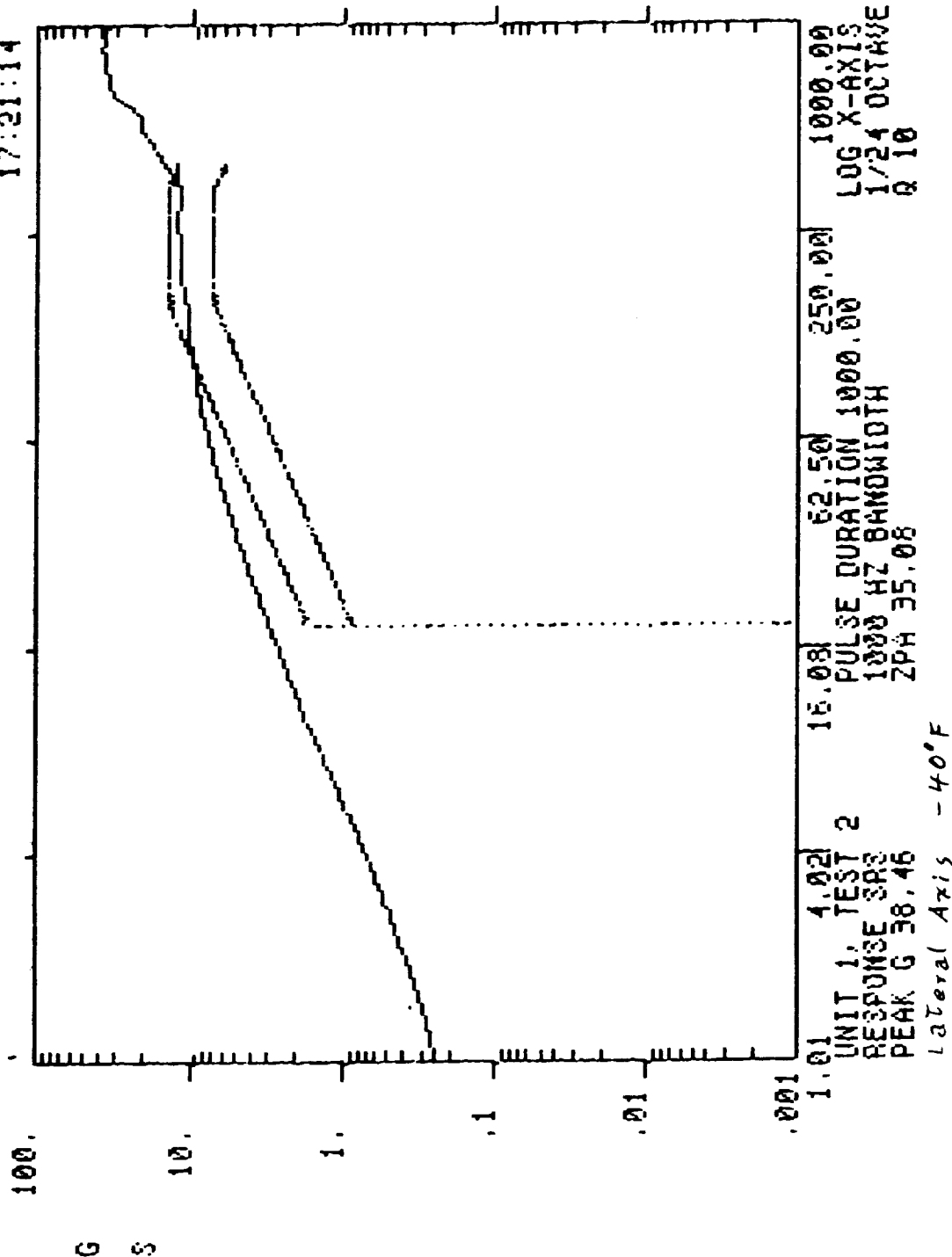
THIOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 21-NOV-89 17:16:09



C-10

Shock #4

THICKOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 21-NOV-89 17:21:14

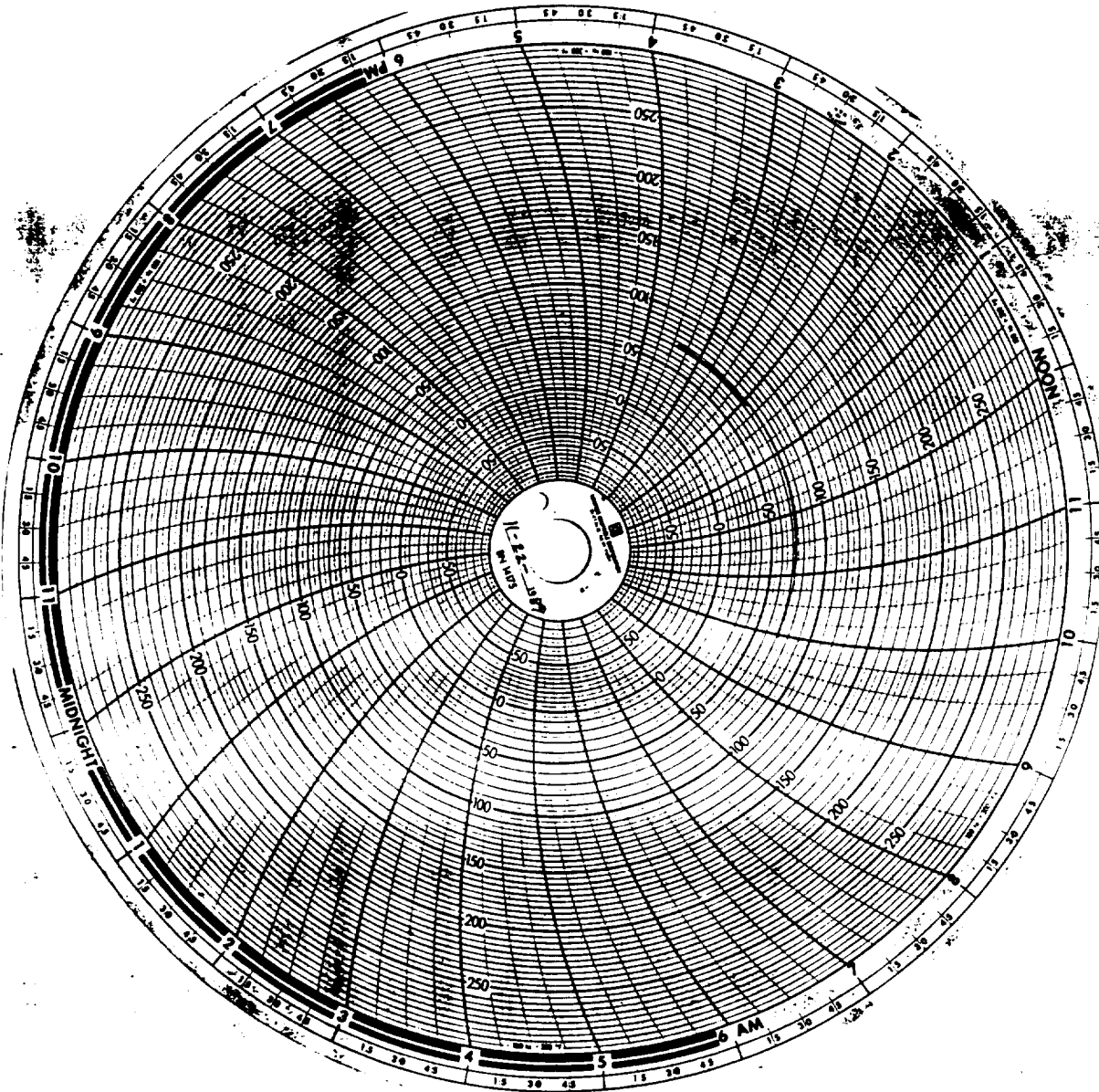


C-11

Shock #5

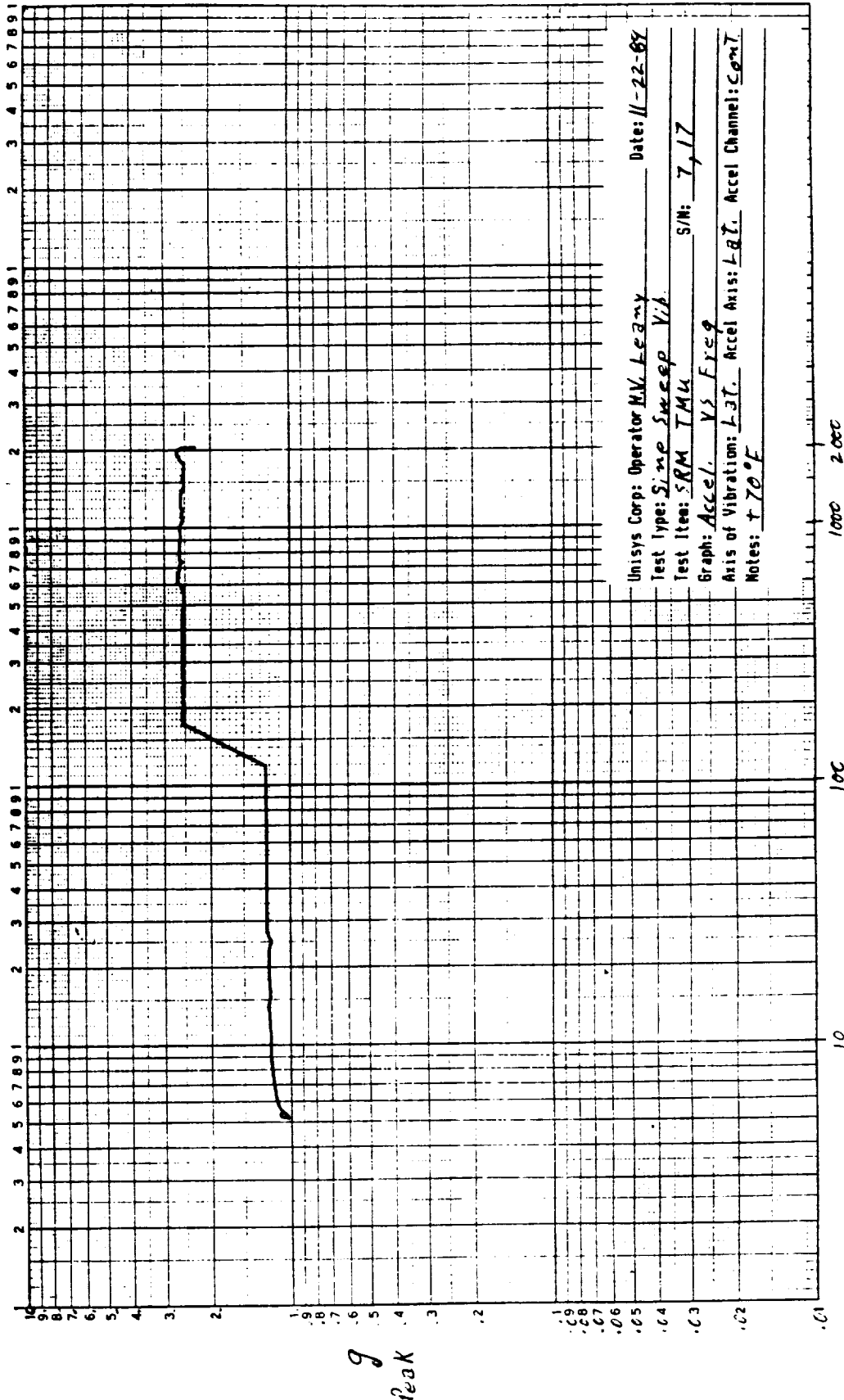
APPENDIX D
UNISYS CONTROL AND RESPONSE DATA FROM
TANGENTIAL AXIS TRANSPORTATION TEST
(70°F ± 10°F)

ORIGINAL PAGE IS
OF POOR QUALITY



D-1

102
UNIVERSITY MICROFILMS
SERIALS ACQUISITION
300 N ZEEB RD
ANN ARBOR MI 48106

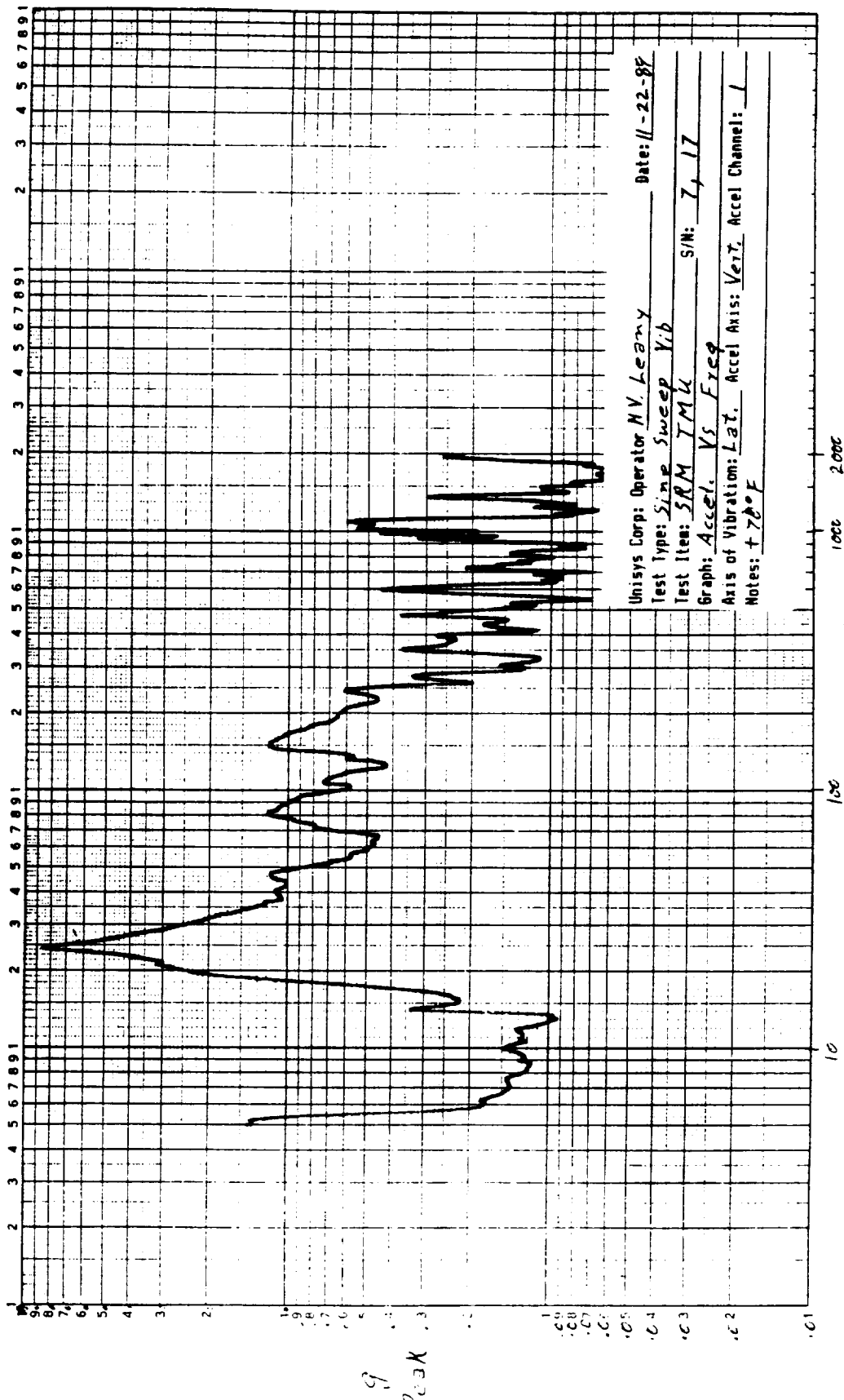


Unisys Corp: Operator M.V. Leamy Date: 11-22-84
 Test Type: Sine Sweep Vib.
 Test Item: SRM TMU S/N: 7,17
 Graph: Accel. vs Freq
 Axis of Vibration: L-R Accel Axis: L-R Accel Channel: Com 7
 Notes: +70°F

Sine Sweep Input
D-2

ORIGINAL PAGE IS
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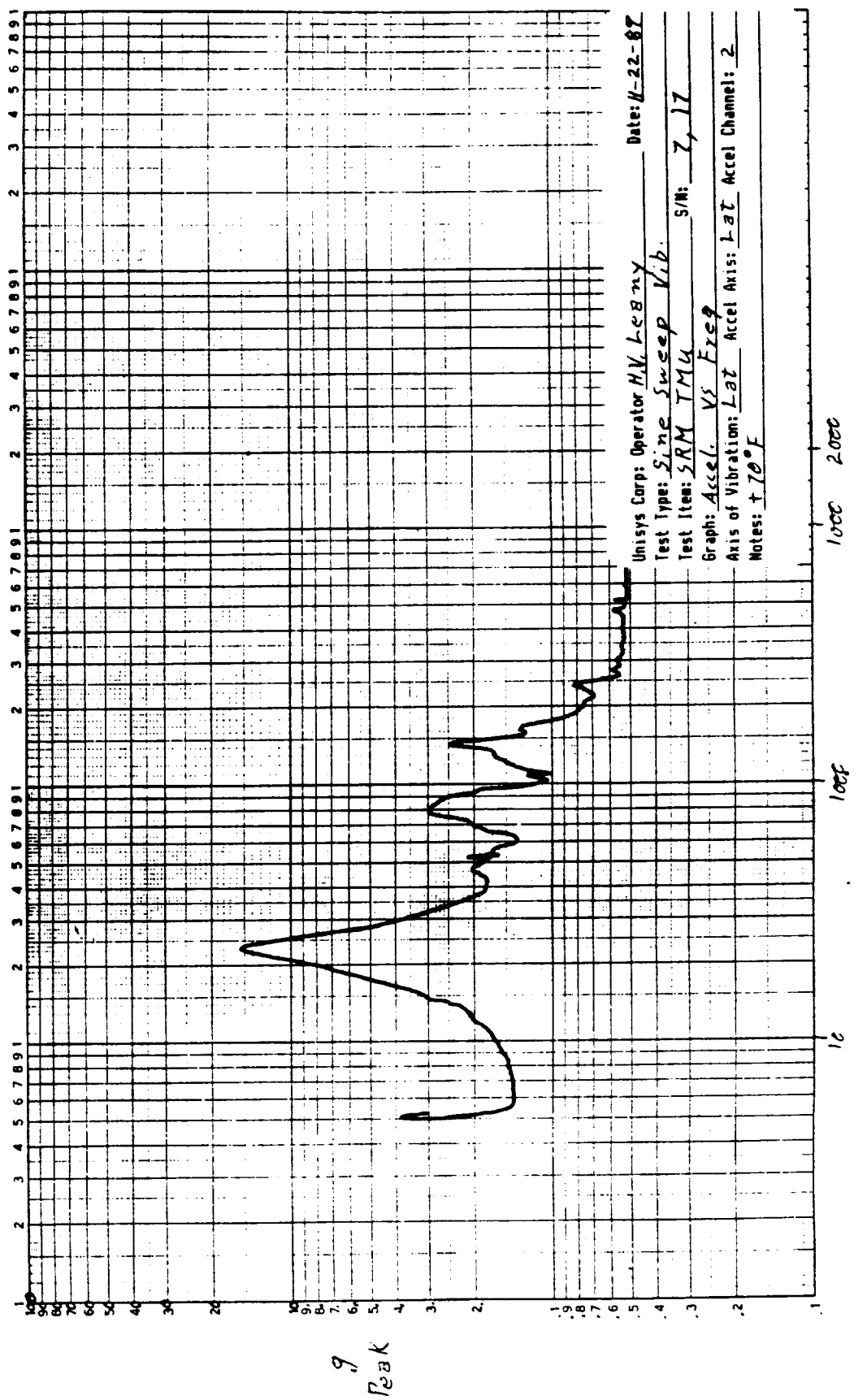
LOGE LOGAN, INC. 358-145
KEUFFEL & ESSER CO. 3-1-1-1-1-1-1
3-1-1-1-1-1-1



Frequency Hz D-3
Sine Sweep Response

LOGAN THERMIL 300-142
KEUFFEL & ESSER CO. PHILADELPHIA
3 AND 5 CYCLES

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OF POOR QUALITY



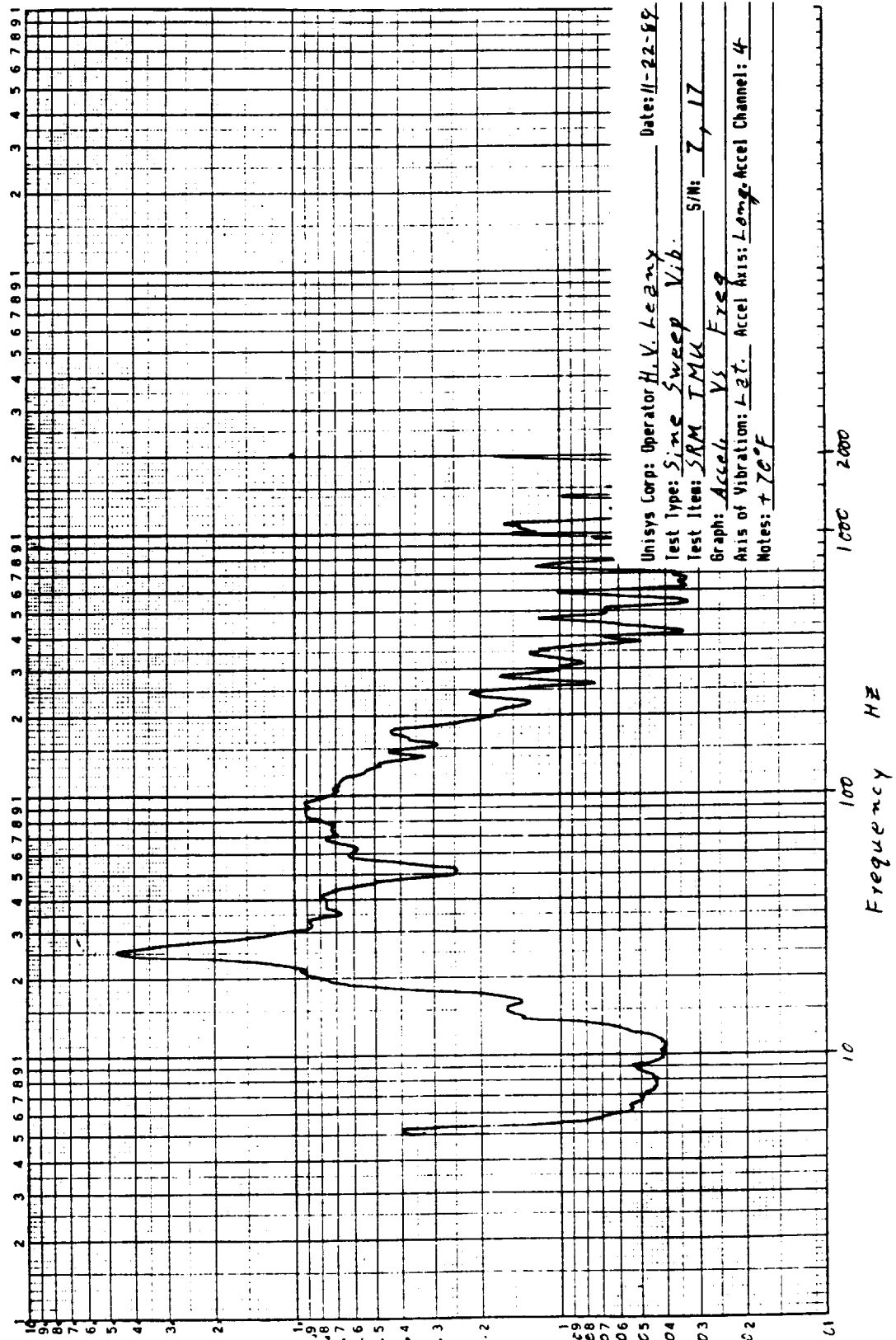
g
Peak

Unisys Corp: Operator HV Leamy Date: 11-22-87
 Test type: Sine Sweep Vib.
 Test Item: SRM TMU S/N: 7, 17
 Graph: Accel. vs Freq
 Axis of Vibration: Lat Accel Axis: Lat Accel Channel: 2
 Notes: + 10°F

Frequency Hz
D-4
Sine Sweep Response

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102 LUQUILMIL 300-140
REUTEL WESSER CO. 100-1
1 X 3 CYCLES

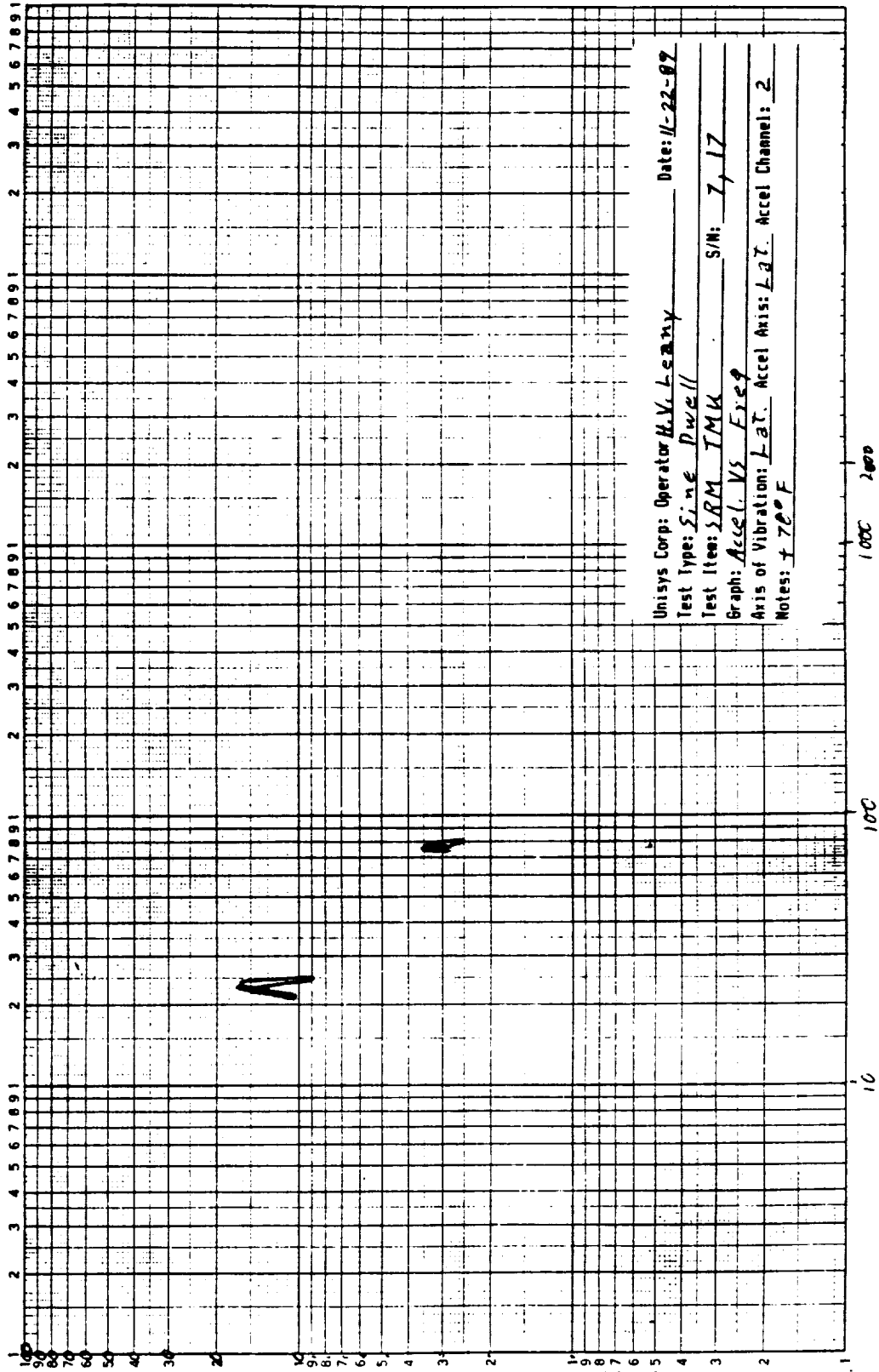


Unisis Corp: Operator H. V. Leary Date: 11-22-88
Test Type: Sine Sweep Vib.
Test Item: SRM TMK S/N: 7, 17
Graph: Accel Vs Freq
Axis of Vibration: L-27 Accel Axis: Long-Accel Channel: 4
Notes: +70°F

D-5
Sine Sweep Response

ORIGINAL PAGE IS
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1502
LUDWIGSMIL 300-140
KEUFEL & ESSER CO. WILMINGTON, DE
1 X 5 CYCLES



Frequency Hz

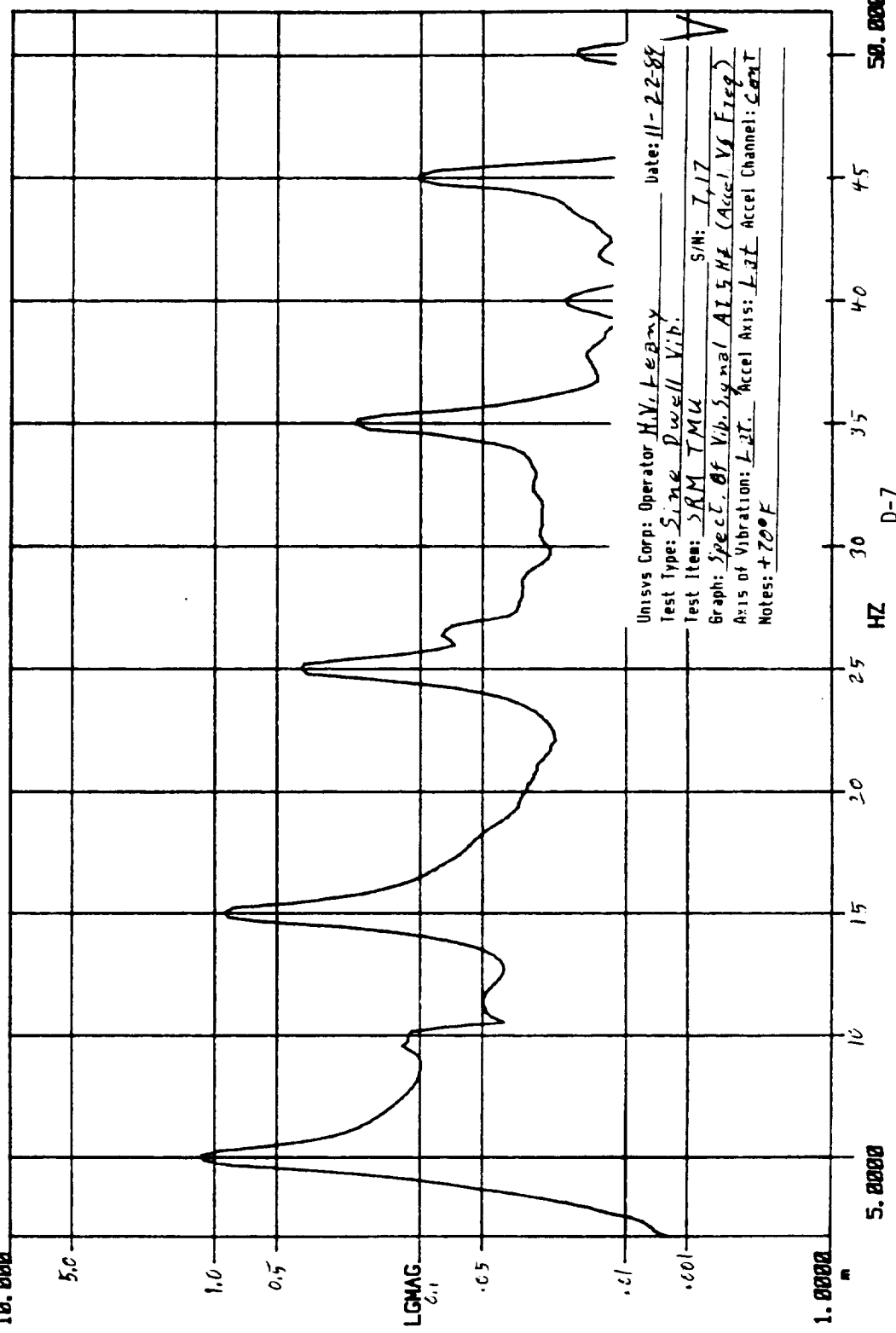
Sine Dwell

D-6

X: 5.0000
A SPEC 1
10.000

Y: 1.1478

#A: 1



Unisys Corp: Operator H.V. Leamy Date: 11-22-88
Test Type: Sine Dwell Vib.
Test Item: SRM TMU S/N: 1,17
Graph: Spect. of Vib. Signal A1.5 Hz (Accel V6 Freq)
Axis of Vibration: Lat. Accel Axis: Lat Accel Channel: Cent
Notes: +70°F

X: 5.0000

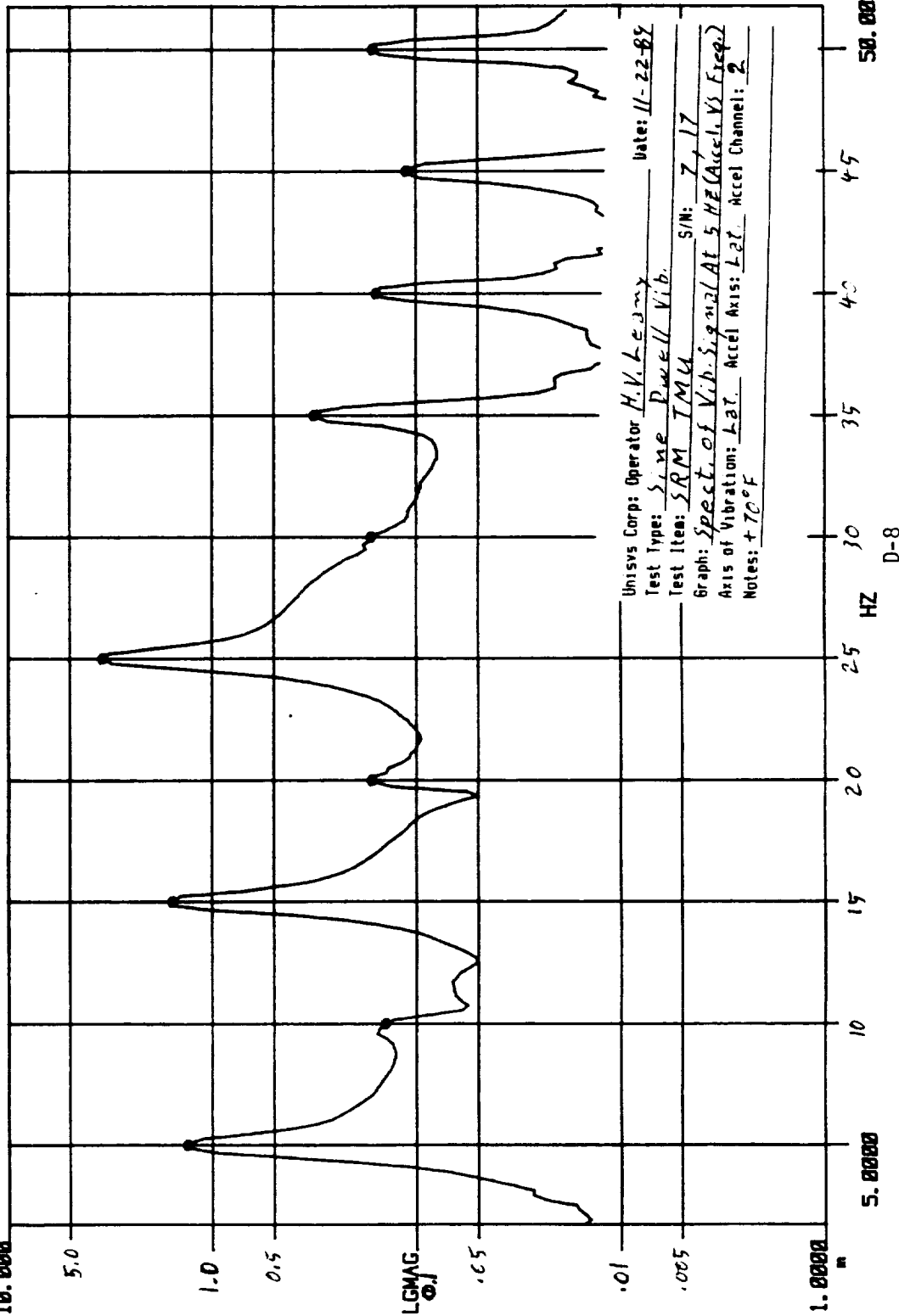
A SPEC 2

10.0000

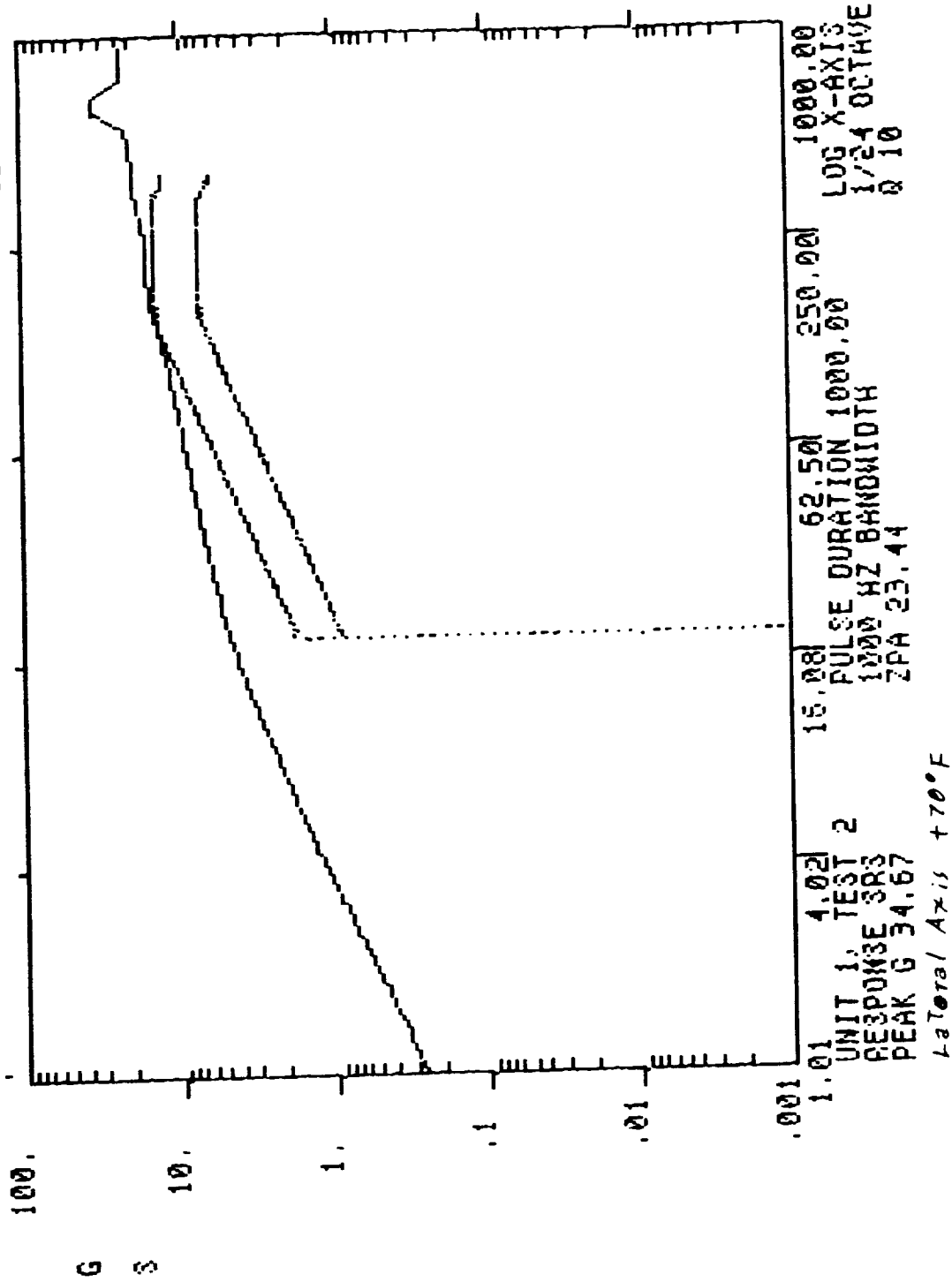
Y: 1.3043

#A: 1

HARMONIC



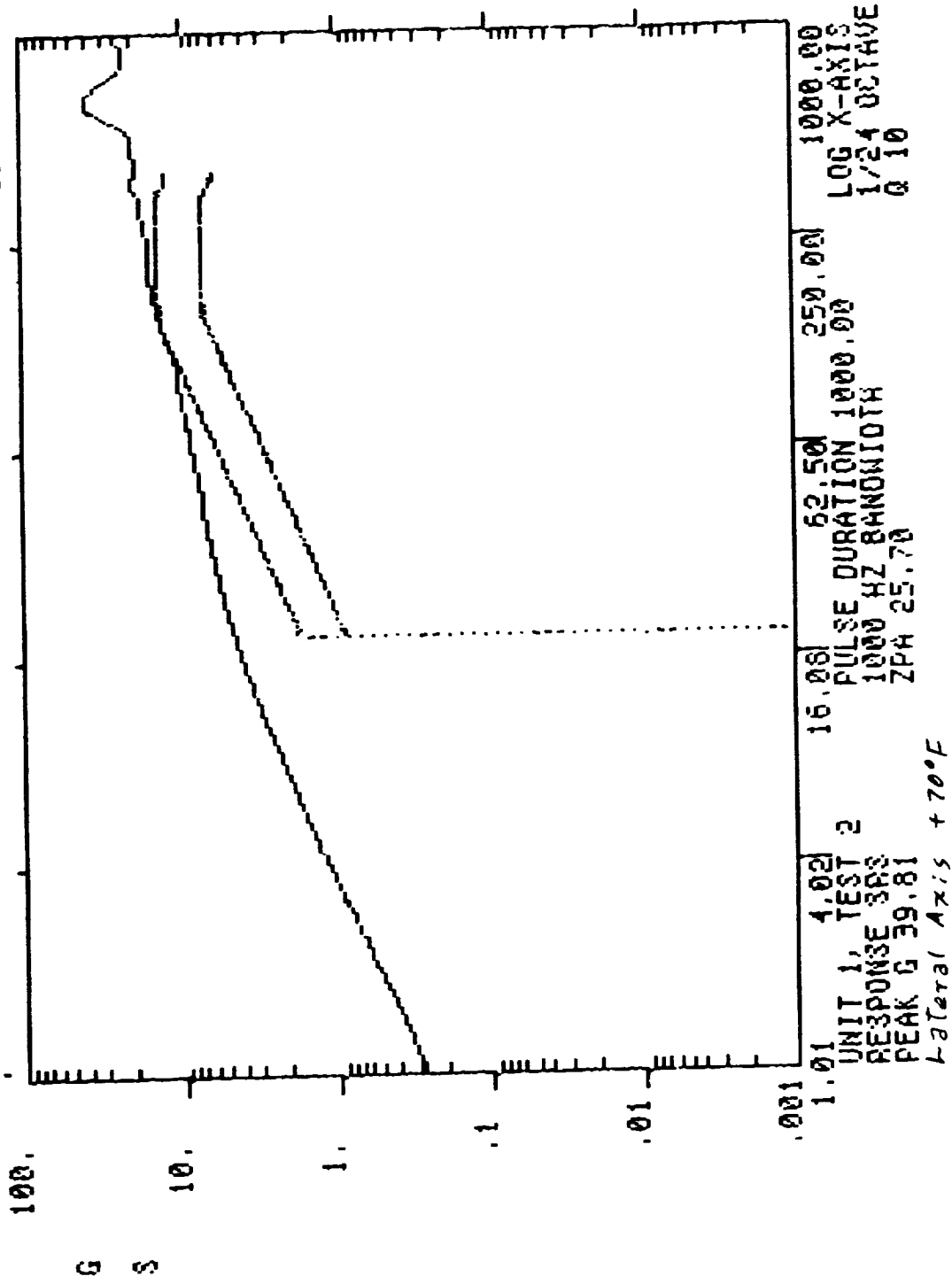
THICKOL SRM THU QUALIFICATION COMPOSITE MAXI MAX 22-NOV-89
13:11:47



D-9

Shock #1

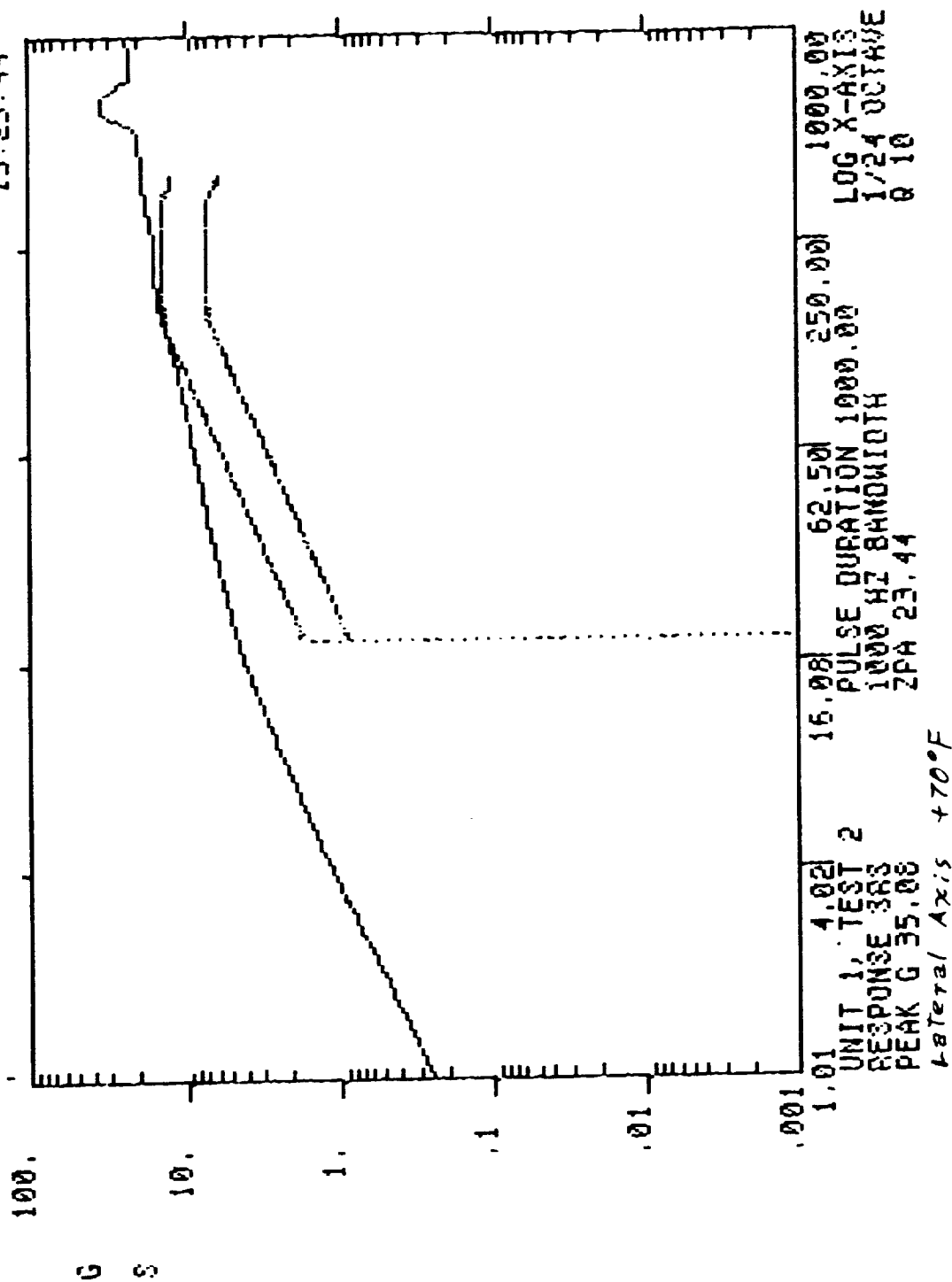
THIOL SRM TMJ QUALIFICATION COMPOSITE MAXI MAX 22-NOV-69 13:19:27



D-10

Shock #2

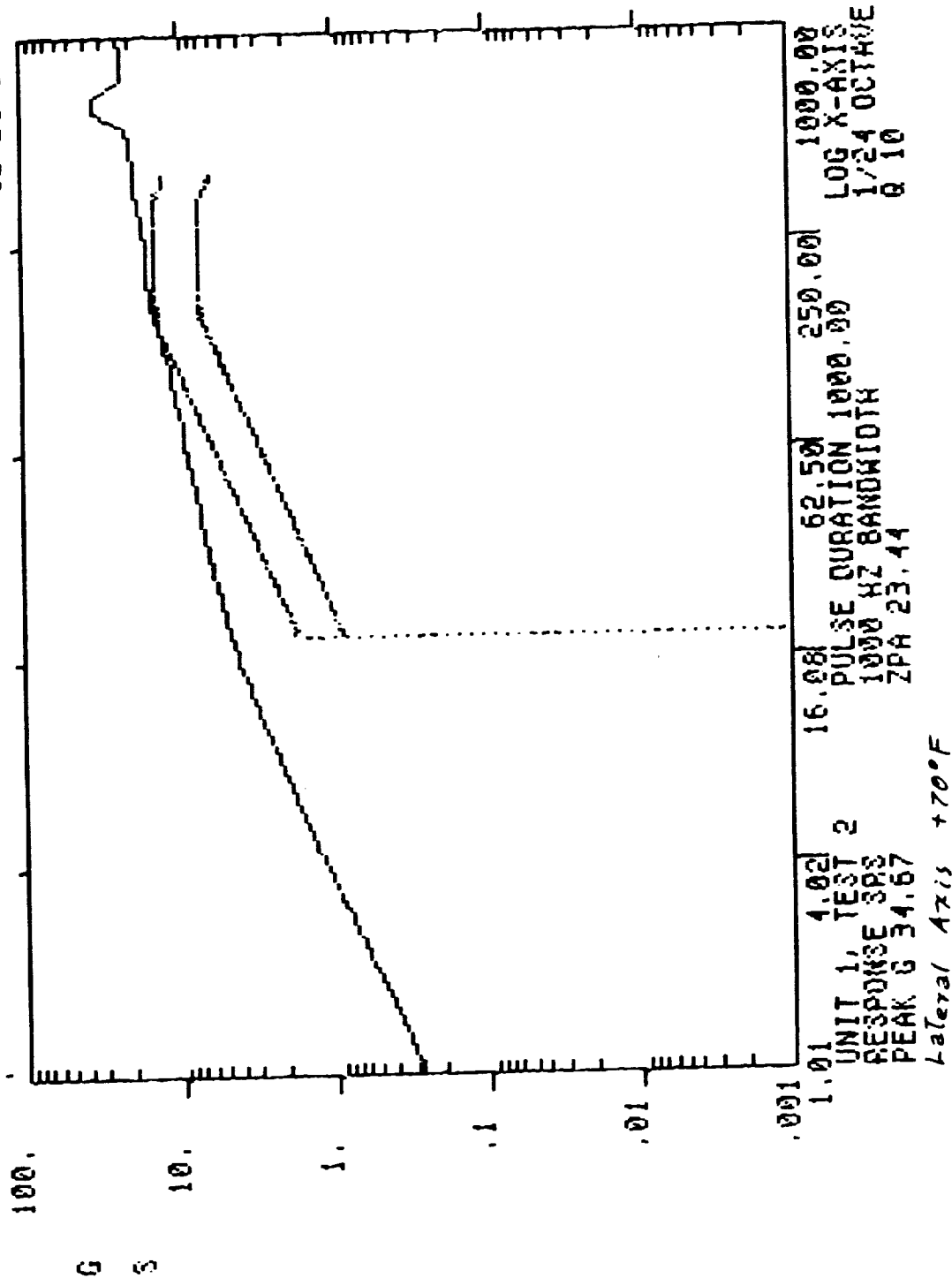
THIOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 22-NOV-89
13:25:44



D-11

Shock # 3

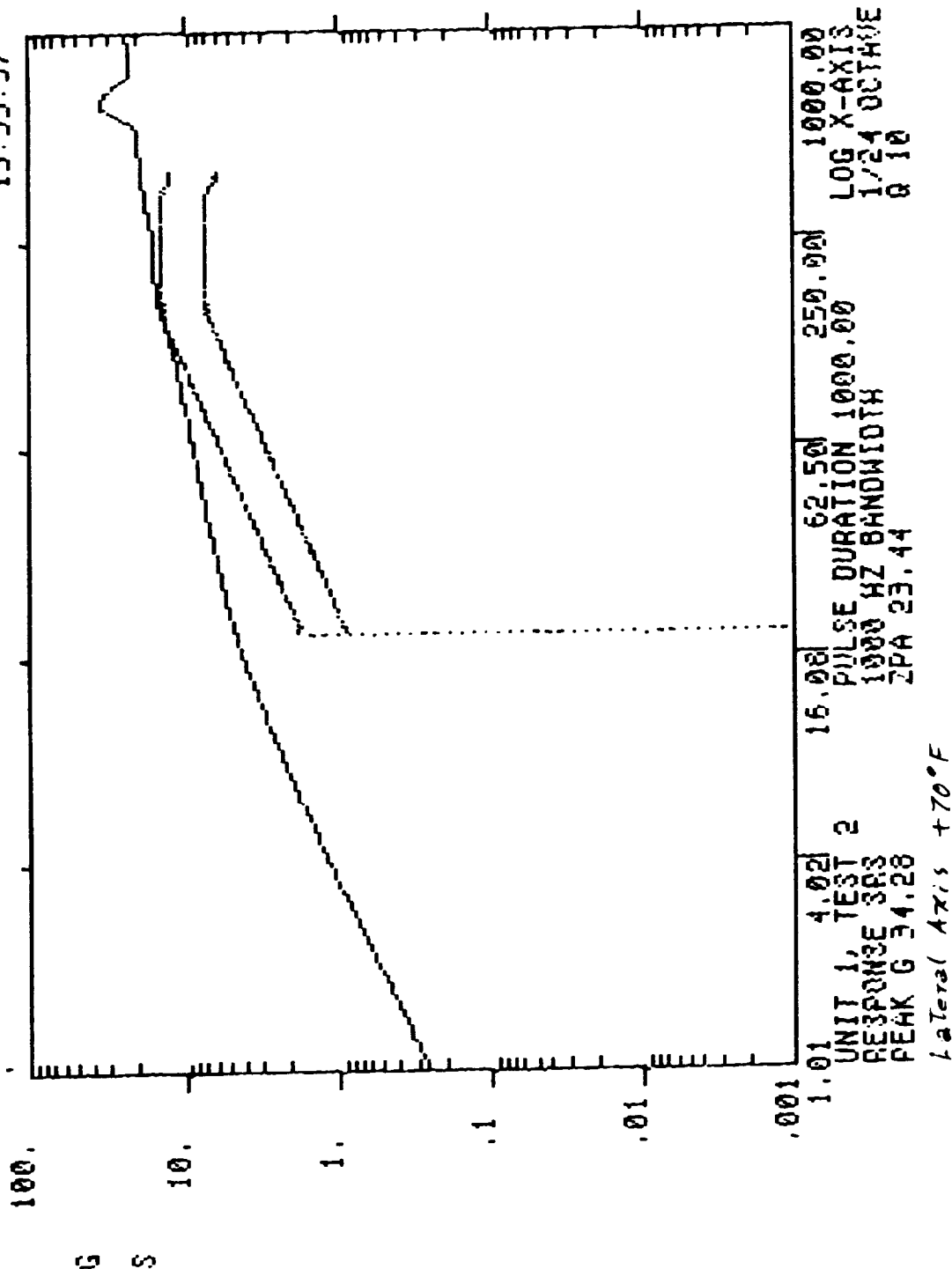
THIOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 22-NOV-89 13:30:34



D-12

Shock #41

THIOL SRH TMU QUALIFICATION COMPOSITE MAXI MAX 22-NOV-89 13:35:37

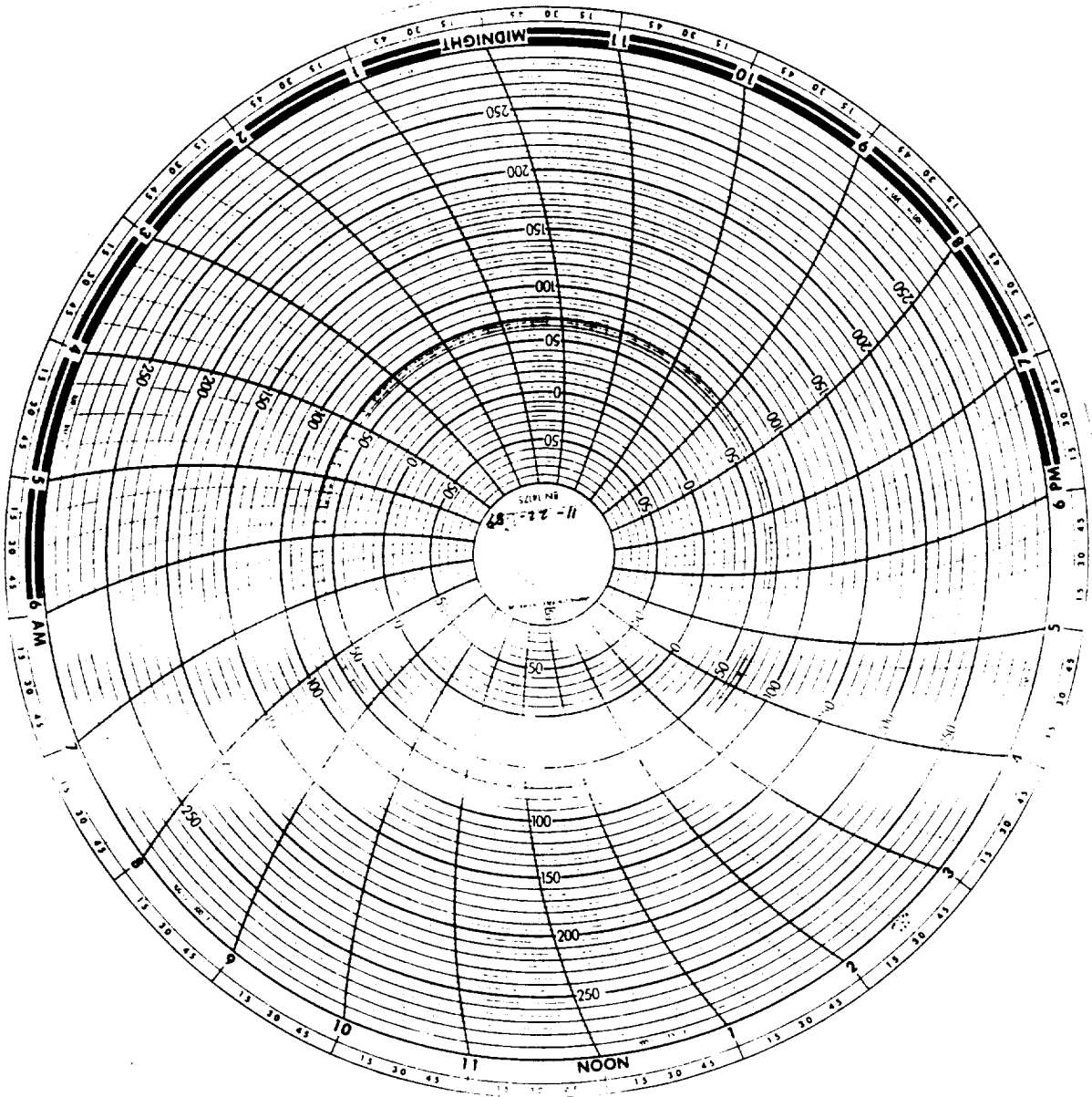


D-13

Shock #5

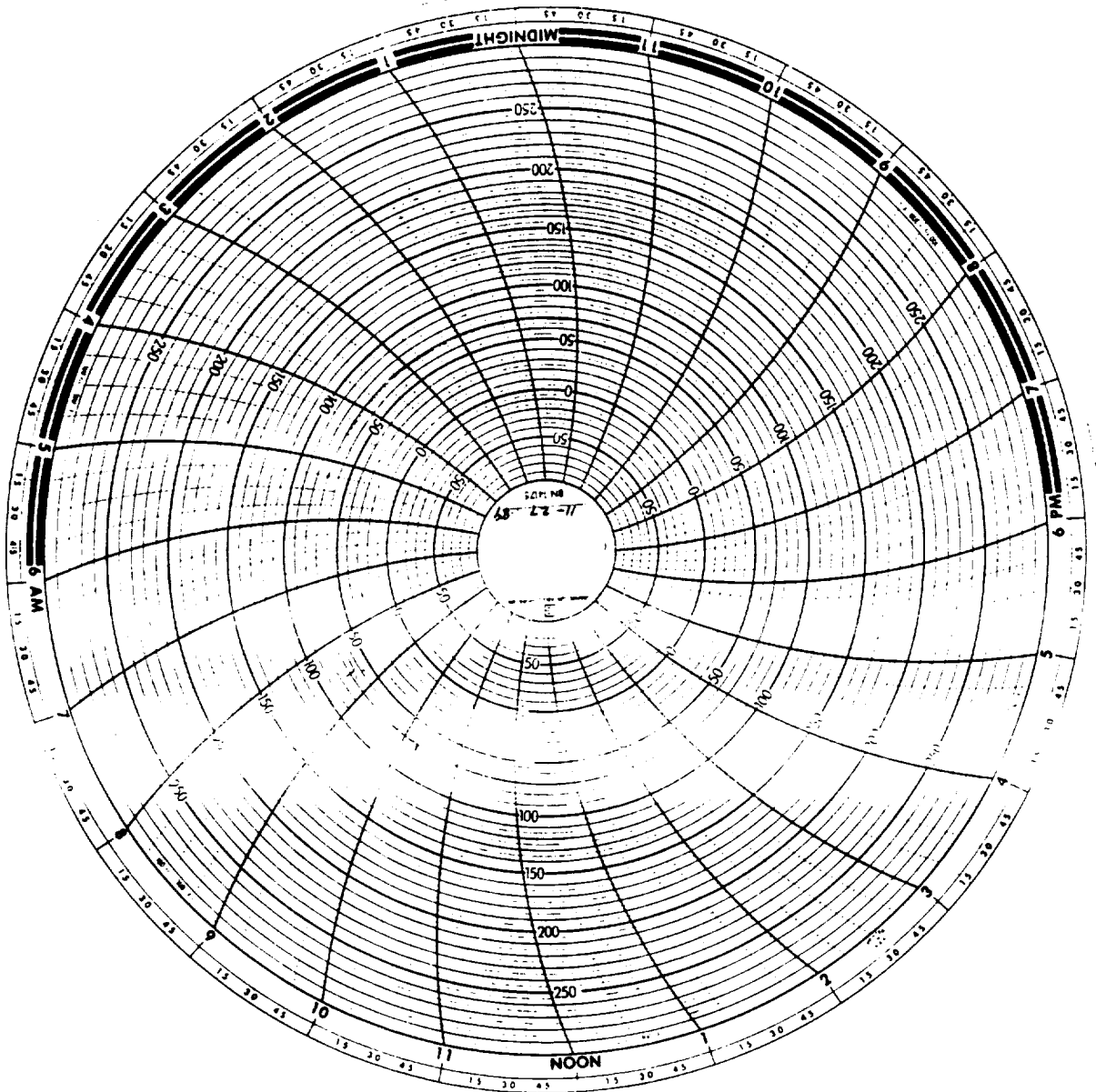
APPENDIX E
UNISYS CONTROL AND RESPONSE DATA FROM
LONGITUDIAL AXIS TRANSPORTATION TEST
(70°F ± 10°F)

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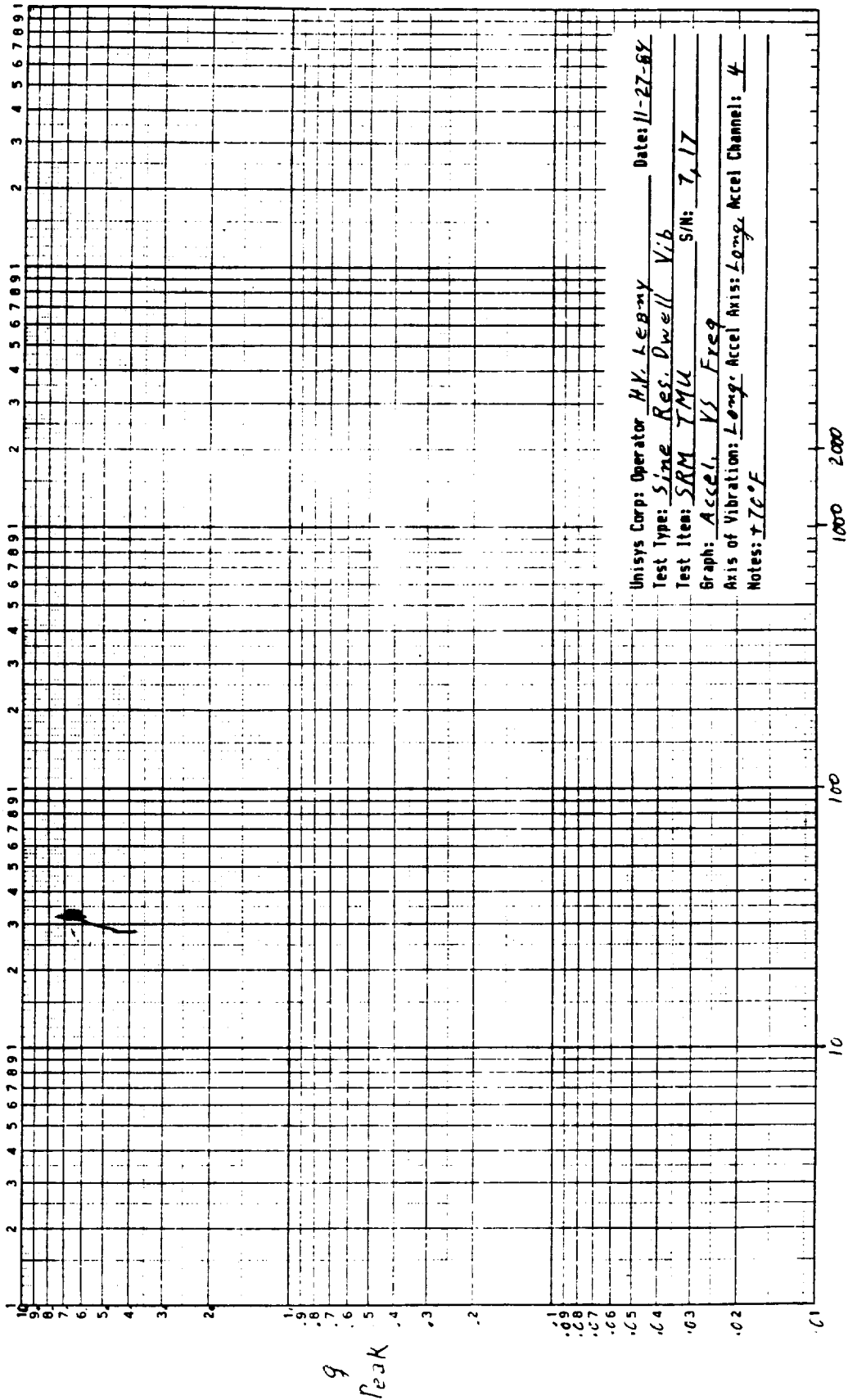


E-1

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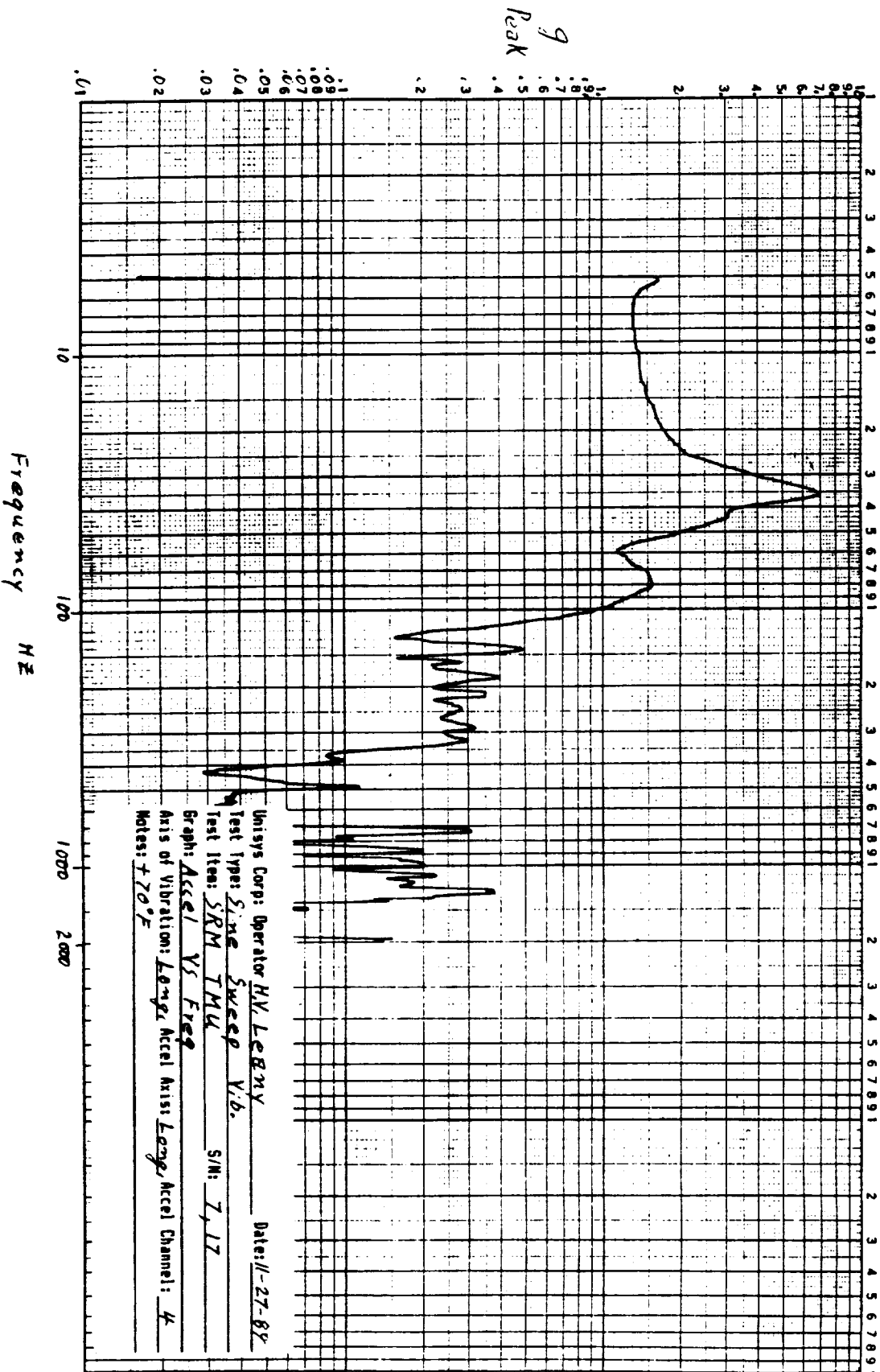
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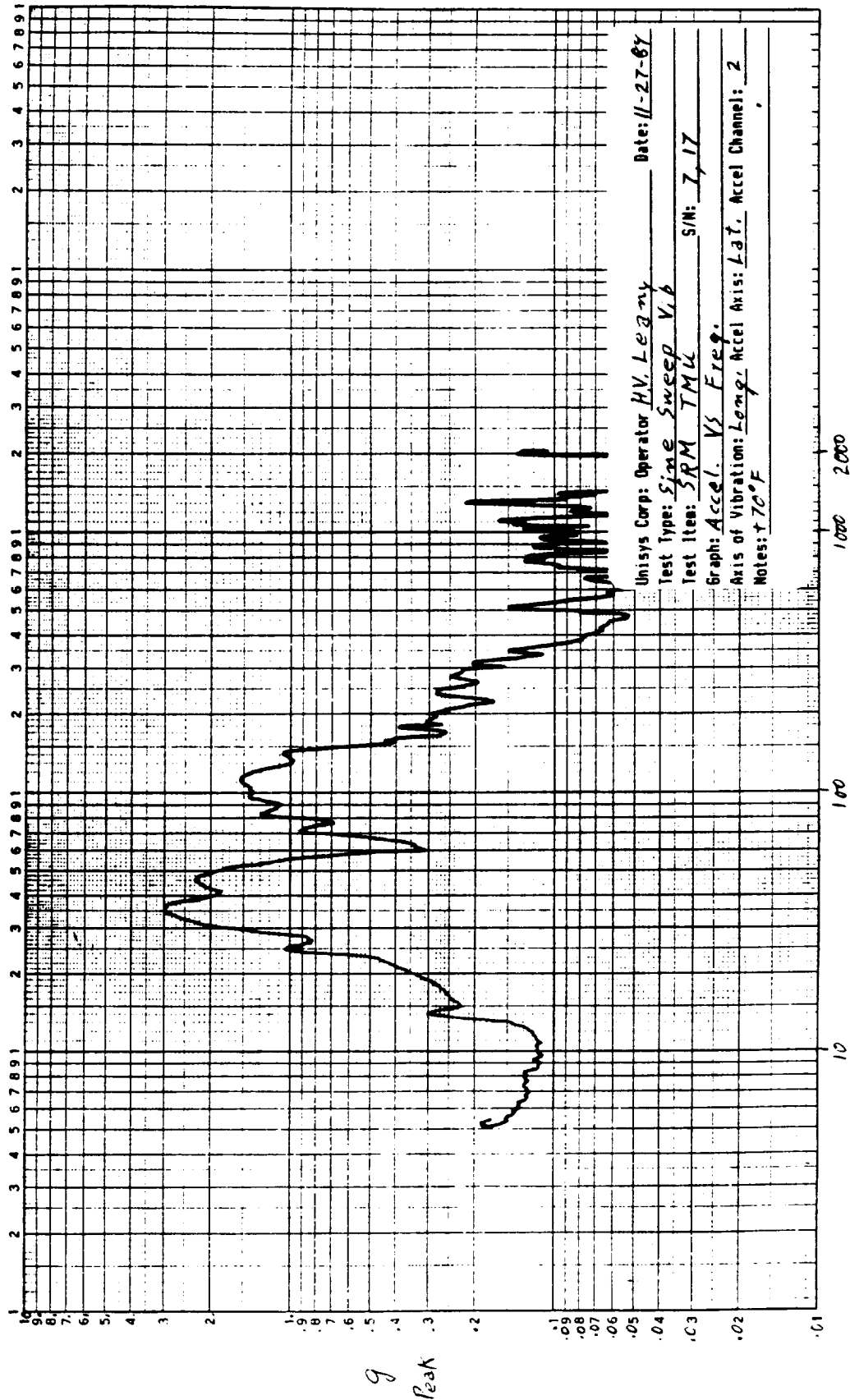
E-3

K&E LUNARILMIL 330-143
KEUFFEL & ESSER CO. WITFILL 11A
3 X 3 CYCLES

E-4
Sine Sweep
face



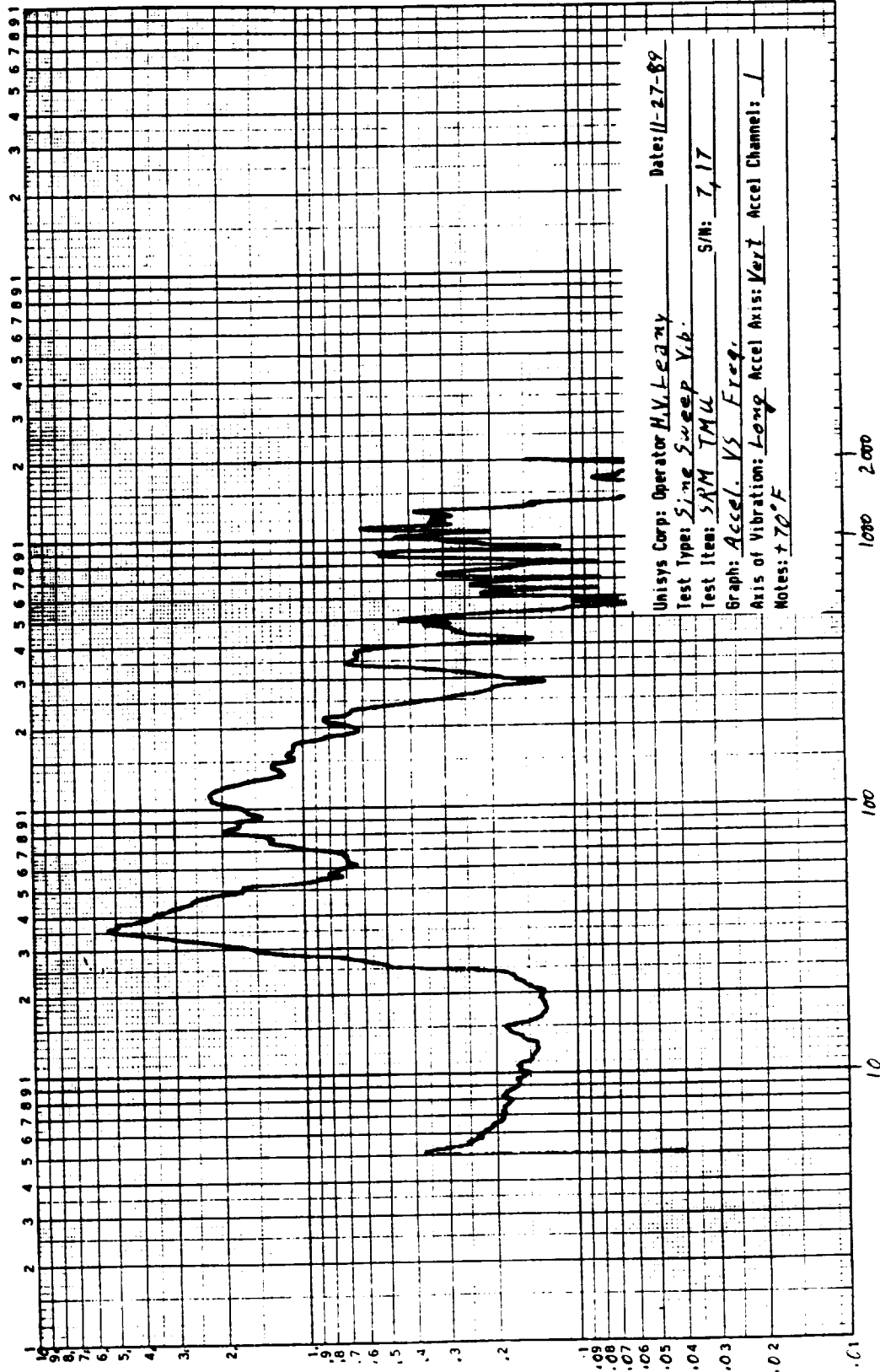
152 LUNAMIMIL 358-125
KEUFEL PAPER CO. JAPAN, J.A.
3 X 5 CIRCLES



Unisys Corp: Operator HV. Leary Date: 11-27-87
 Test Type: Sine Sweep V, b
 Test Item: SRM TMU S/N: 1, 17
 Graph: Accel. VS Freq.
 Axis of Vibration: Long, Accel Axis: Lat, Accel Channel: 2
 Notes: +70°F

Frequency Sweep ~~Response~~ E-5
 Sine Response

LOGAN THMIC 300-120
KEUPPEL BESSER CO. 3.8 CYCLES

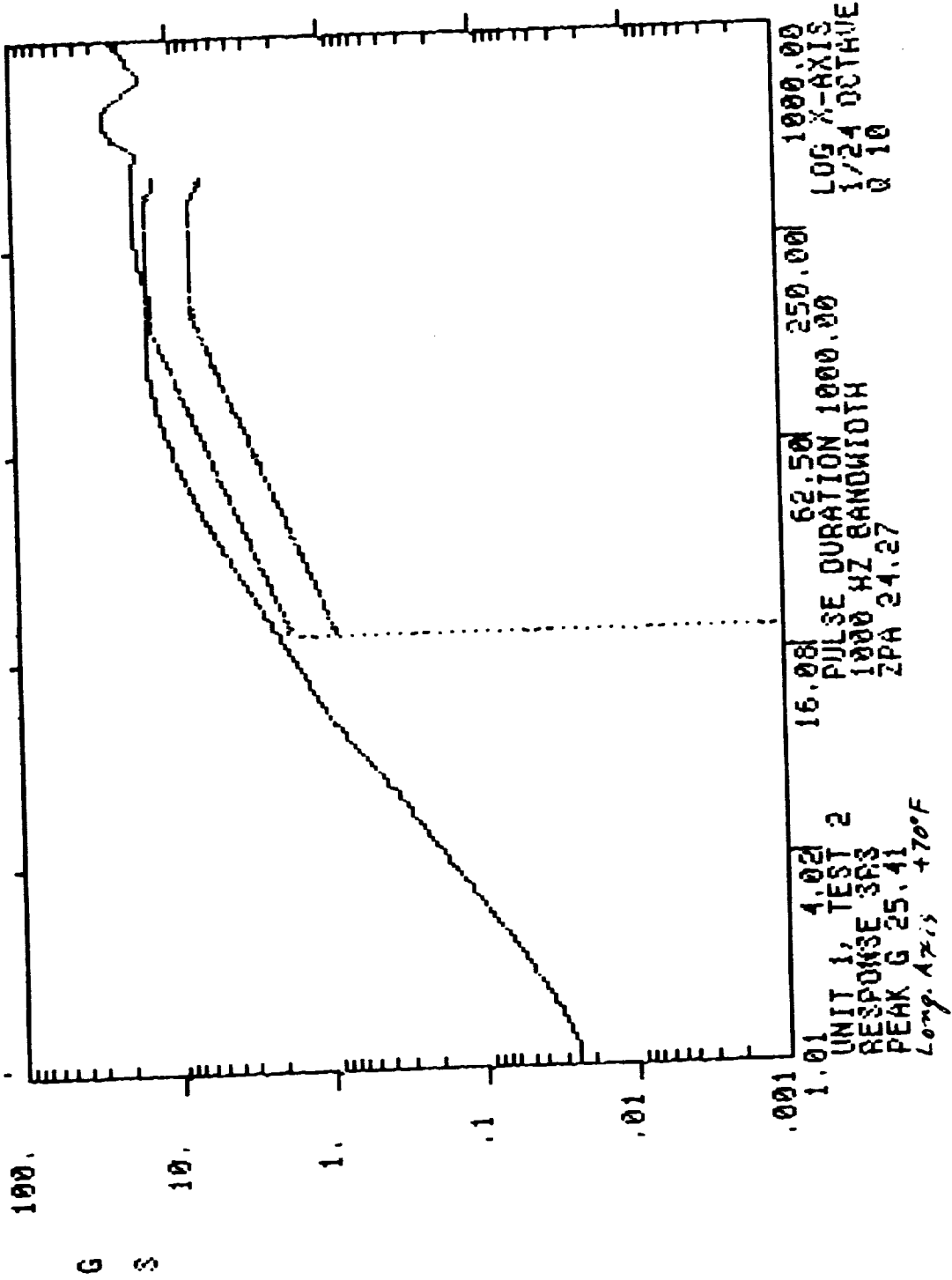


Frequency ~~Sweep~~ /
Sine Response

102
 LUGAHHMIC 350-1423
 KEUFFEL & ESSER CO. PRINTING
 3 X 5 CIRCLES



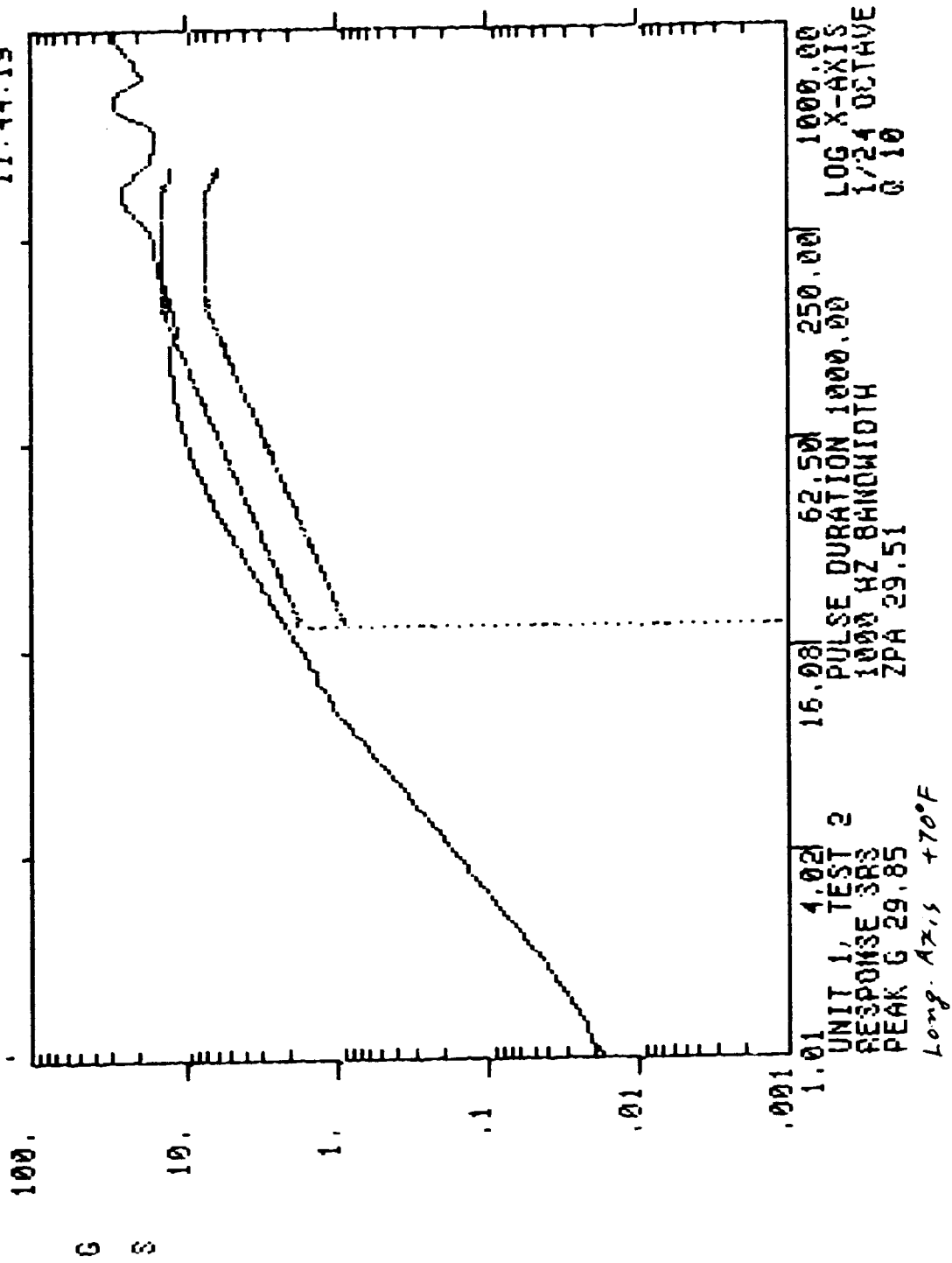
THICKOL SRM TMJ QUALIFICATION COMPOSITE MAXI MAX 27-NOV-89 11:38:42



E-8

Shock #1

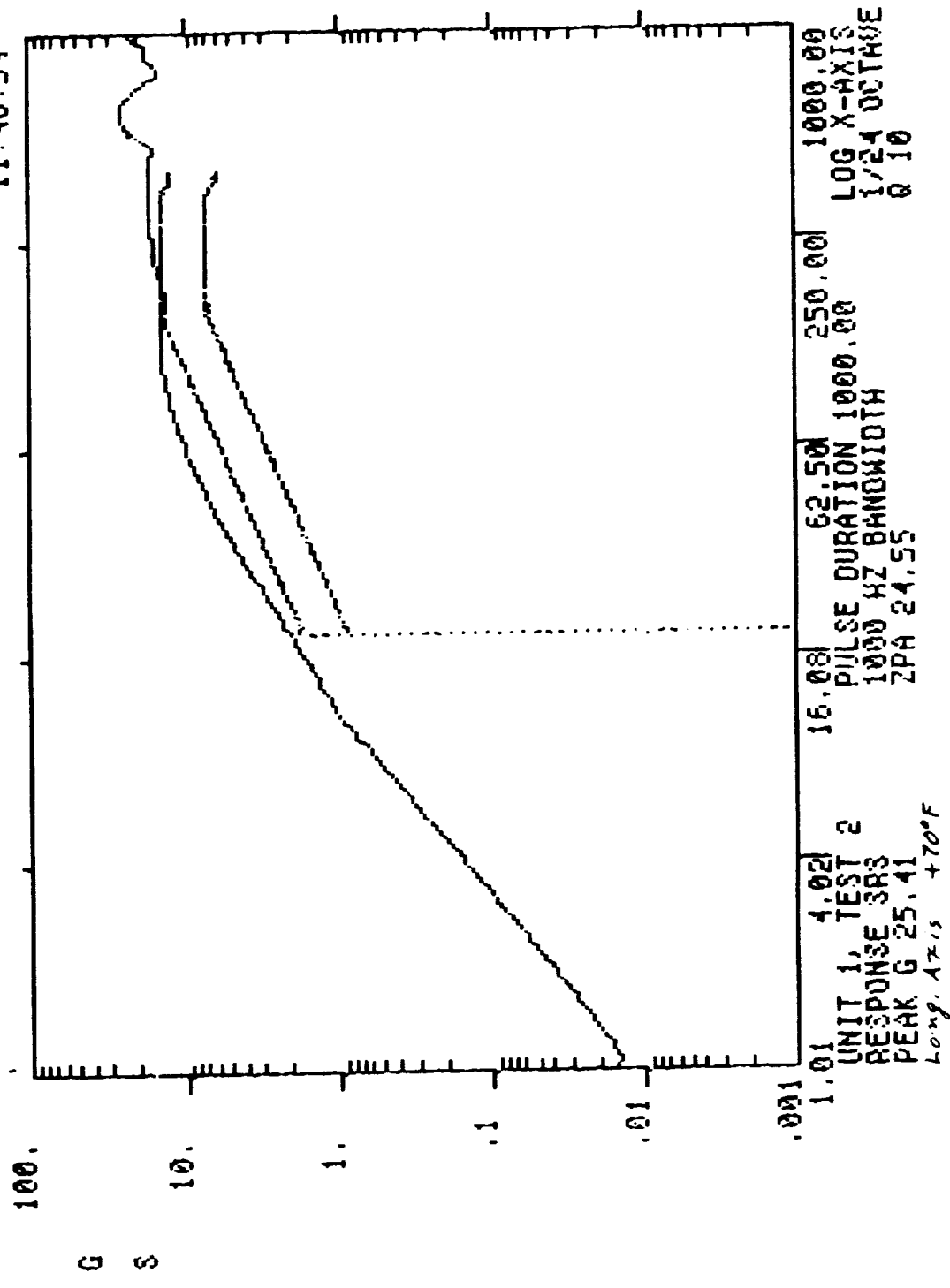
THIOLKOL SAM TMU QUALIFICATION COMPOSITE MAXI MAX 27-NOV-89 11:44:19



E-9

Snack #2

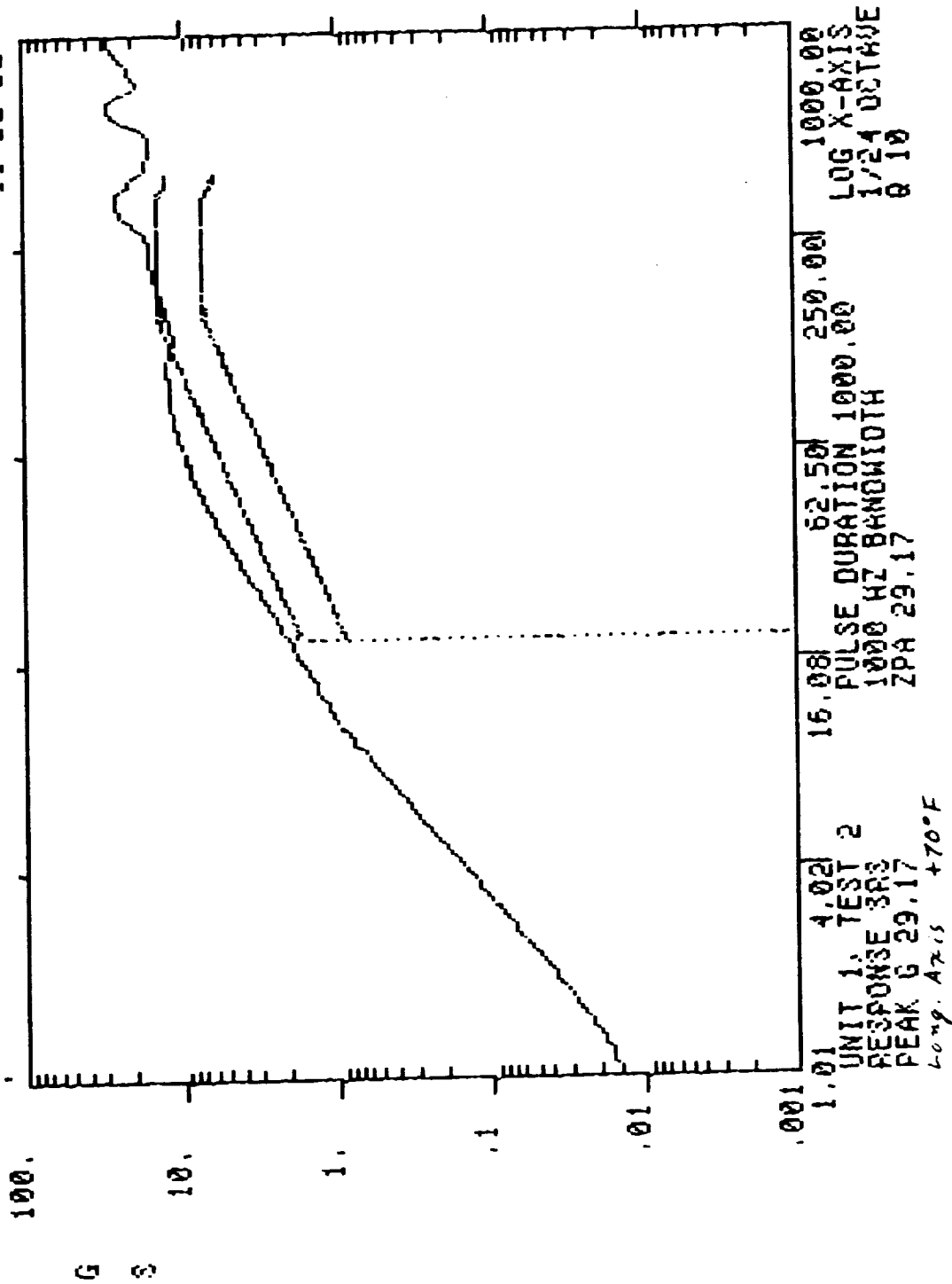
THIOL SRH TMU QUALIFICATION COMPOSITE MAXI MAX 27-NOV-89 11:48:34



E-10

Shuc. K #3

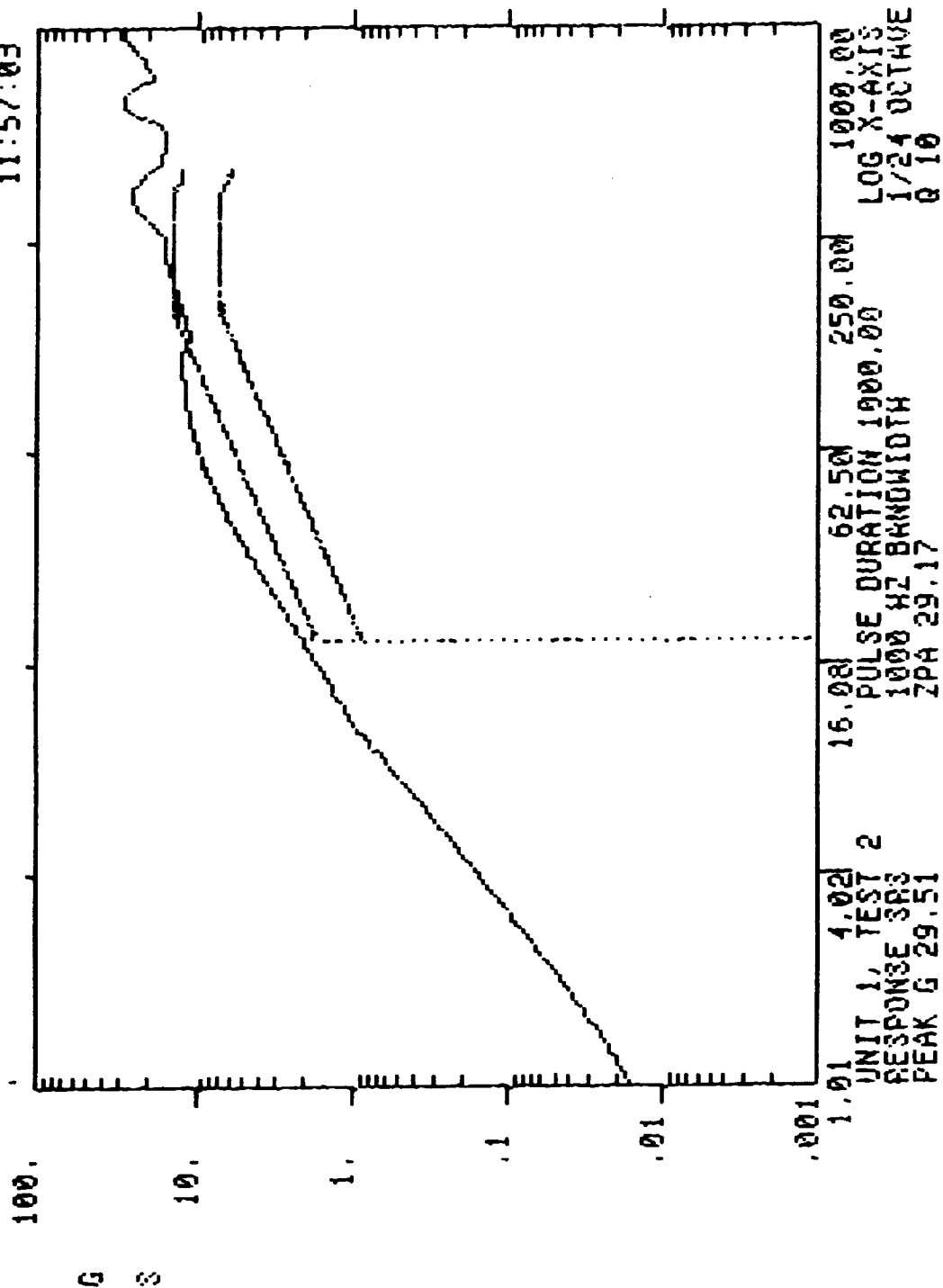
THIOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 27-NOV-89 11:52:52



E-11

Shack #4

THIOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 27-NOV-69 11:57:03



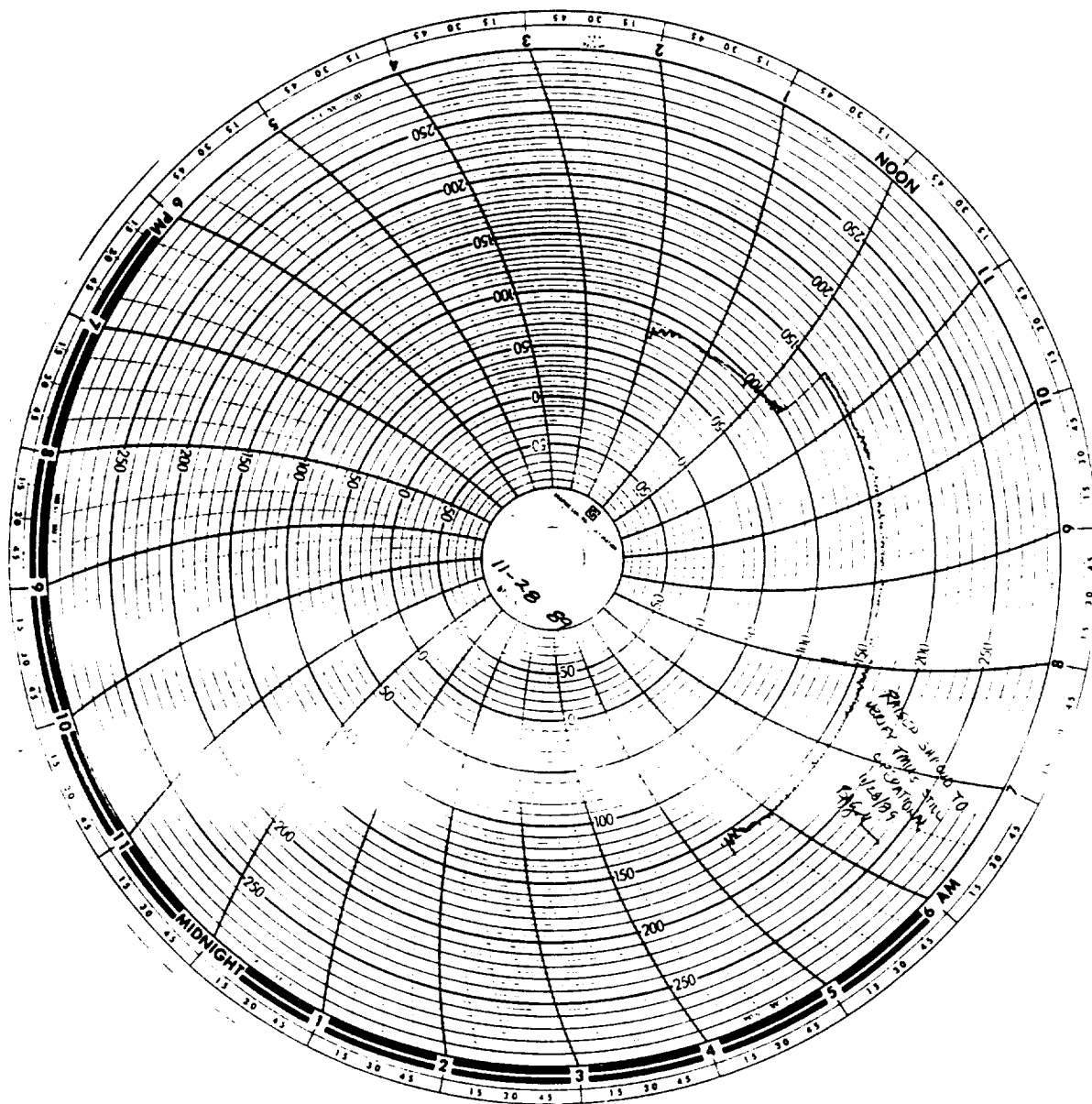
Long Axis +70°F

E-12

Shock #5

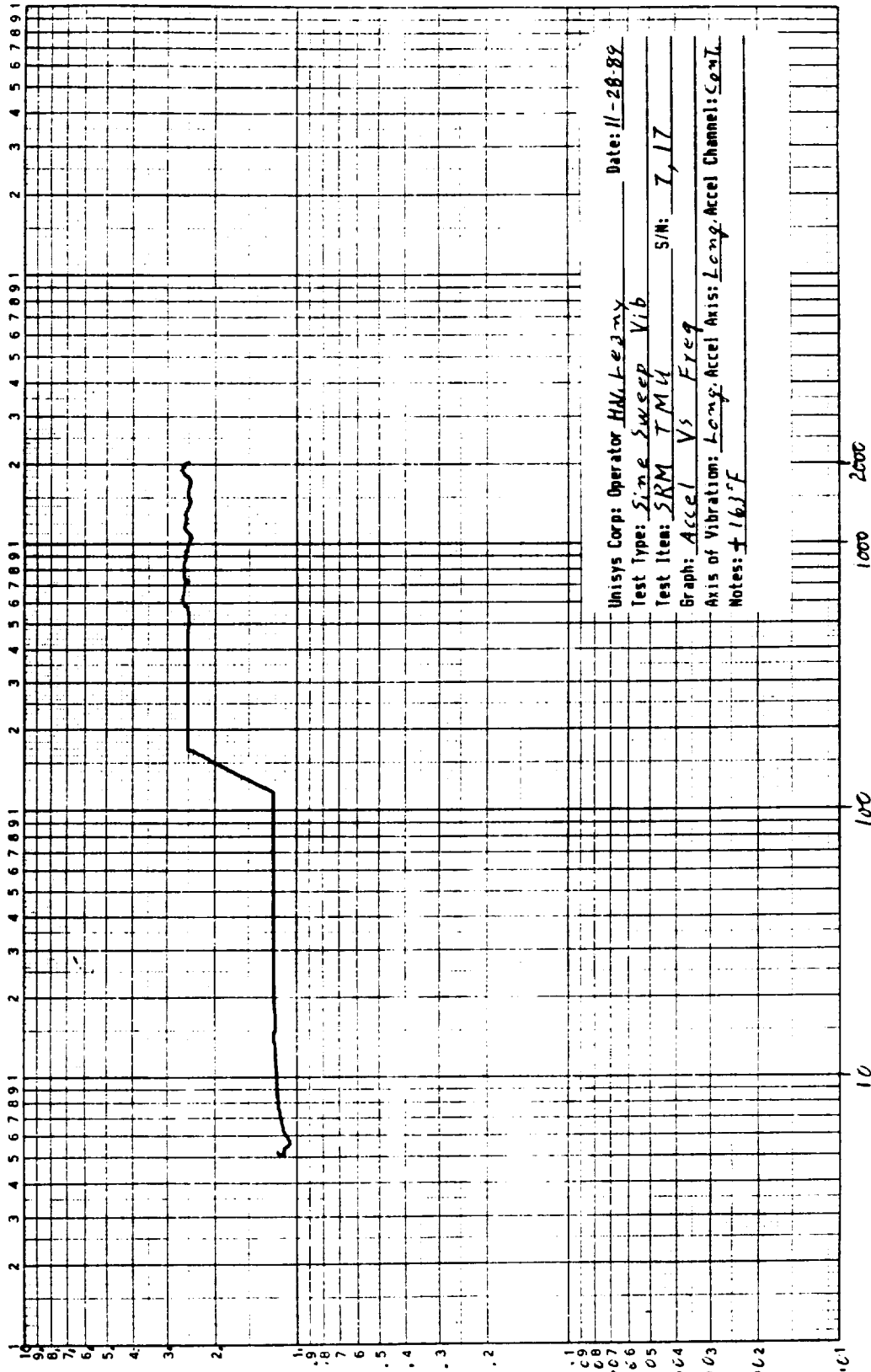
APPENDIX F
UNISYS CONTROL AND RESPONSE DATA FROM
LONGITUDIAL AXIS TRANSPORTATION TEST
(163°F ± 10°F)

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F-1

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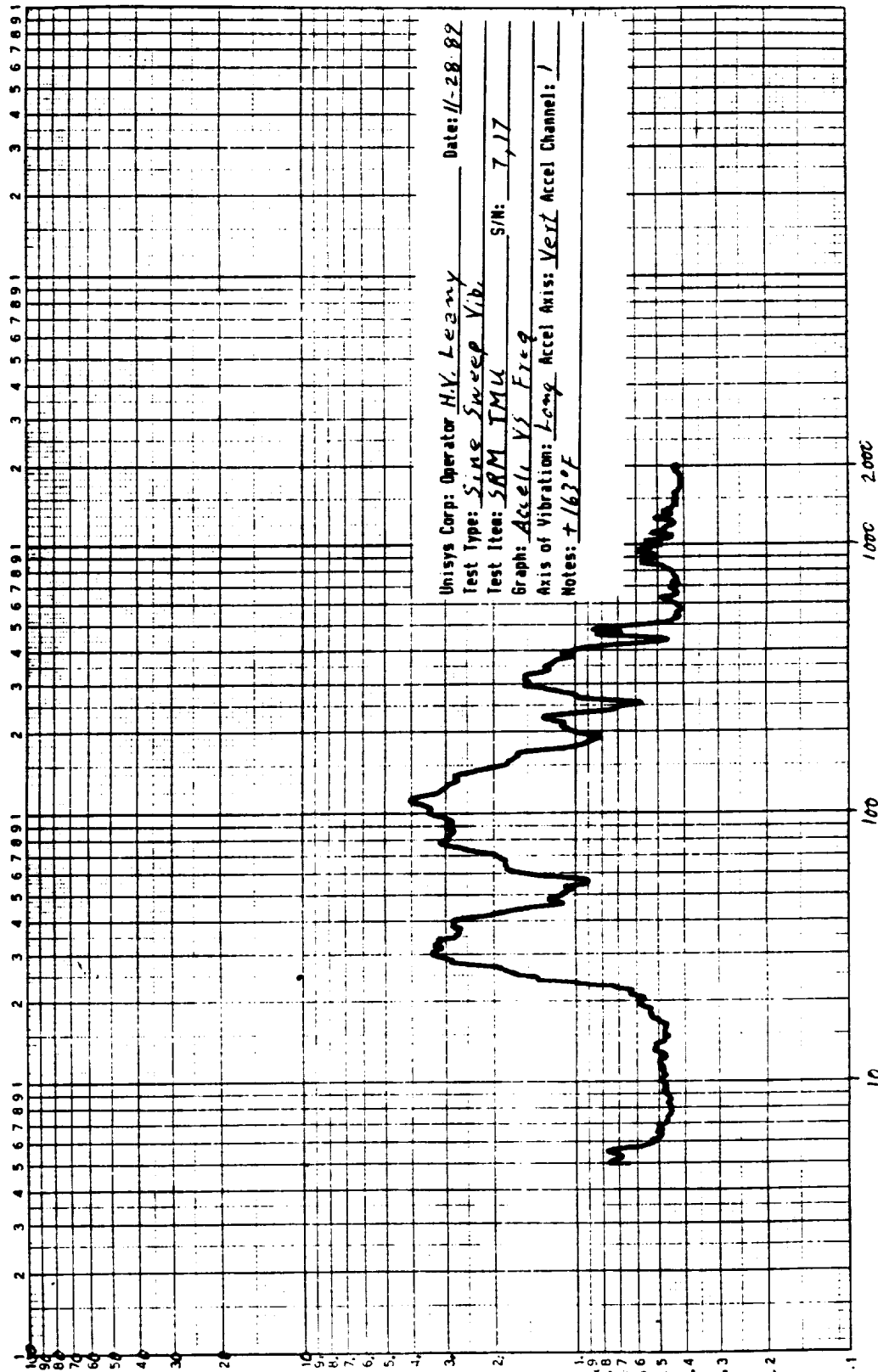
9
Peak

Unisys Corp: Operator H.M. Feary Date: 11-28-89
 Test Type: Sine Sweep Vib
 Test Item: SRM TMU S/N: 1, 17
 Graph: Accel Vs Freq
 Axis of Vibration: Long. Accel Axis: Long. Accel Channel: Cont.
 Notes: + 163°F

Frequency Hz
~~Sine Sweep~~ Input F=2

K&A LOGAN/THMIL 300-123
 NEUFEL & SERRA
 343 CYCLES

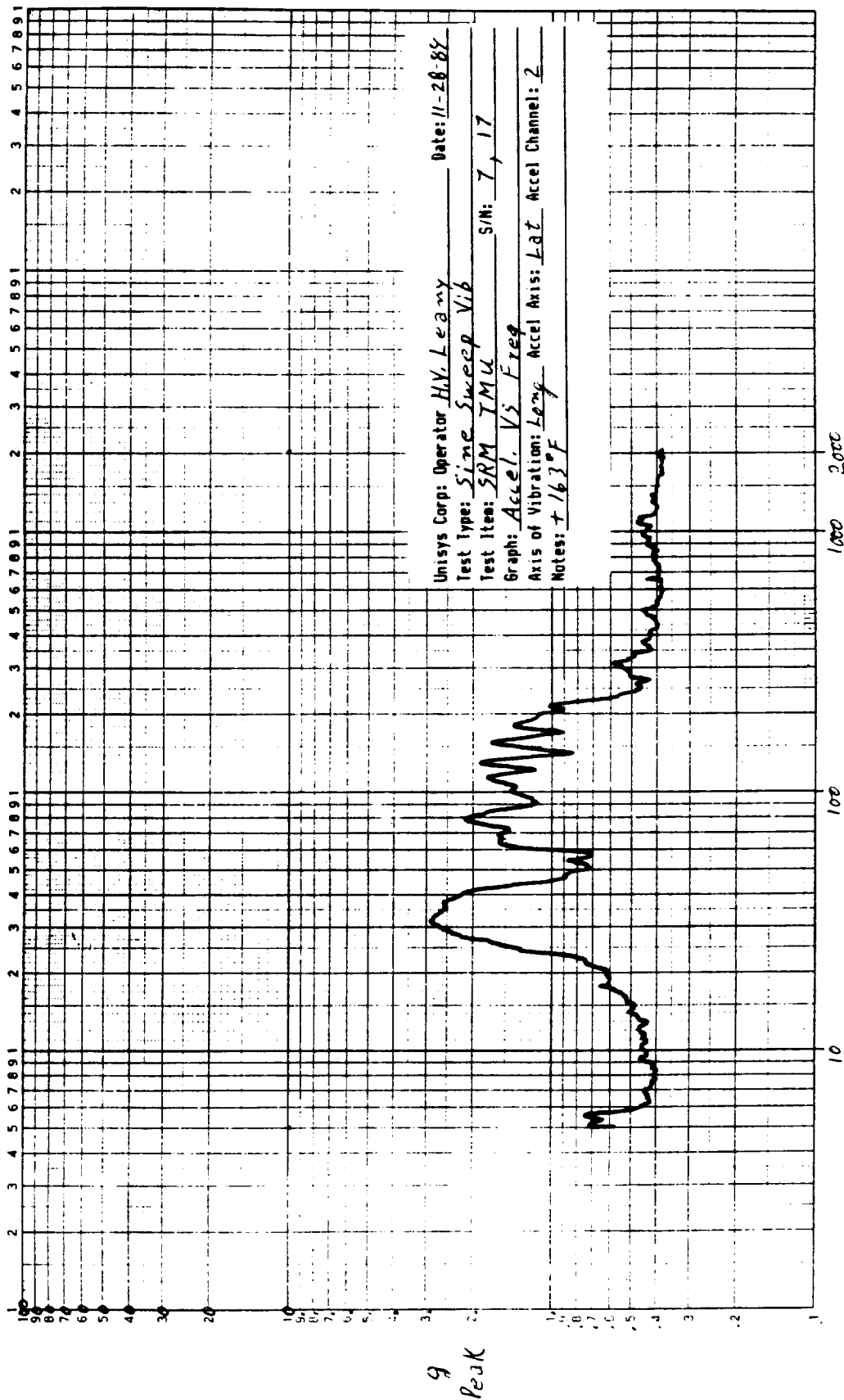
LOGARITHMIC 300-120
KEUTZLE MESSING CO. J1111-1
3 X 5 CYCLES



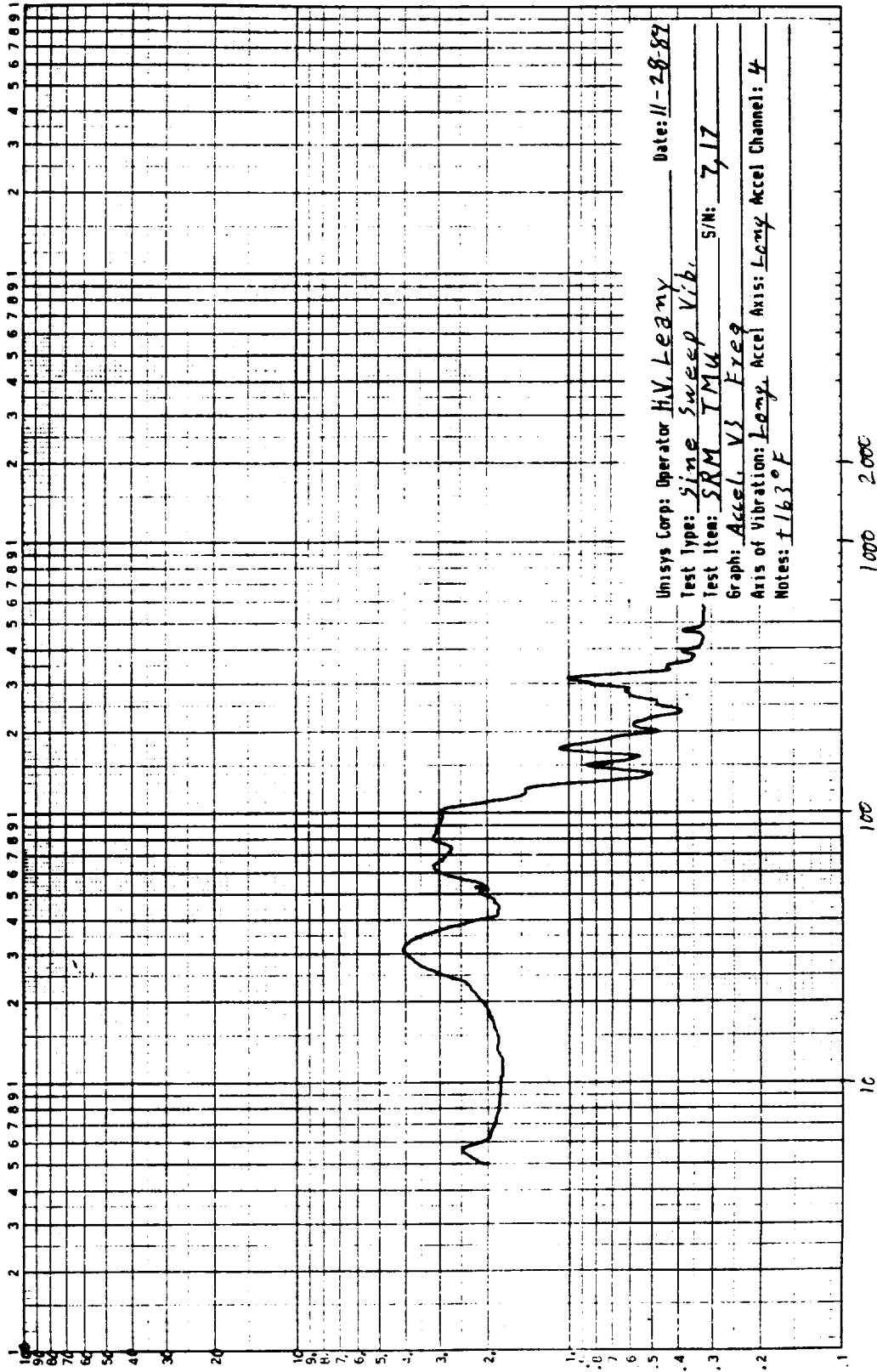
9
Peak

Frequency Hz
Sine Sweep Response

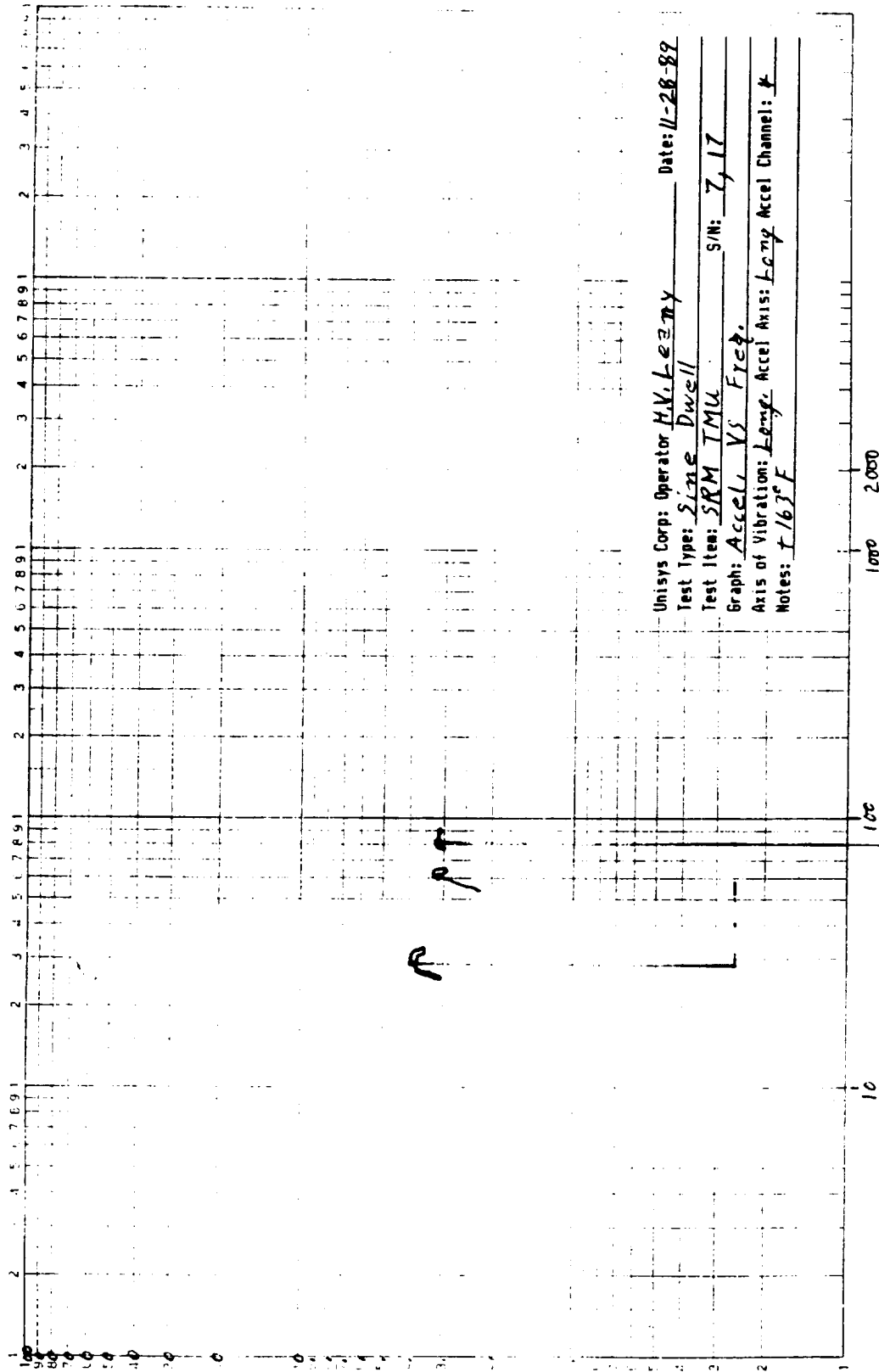
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K&S LOGAN THOMAS 300-140
KEUFFEL & ESSER CO. WILM. D.
3 X 5 CYCLES



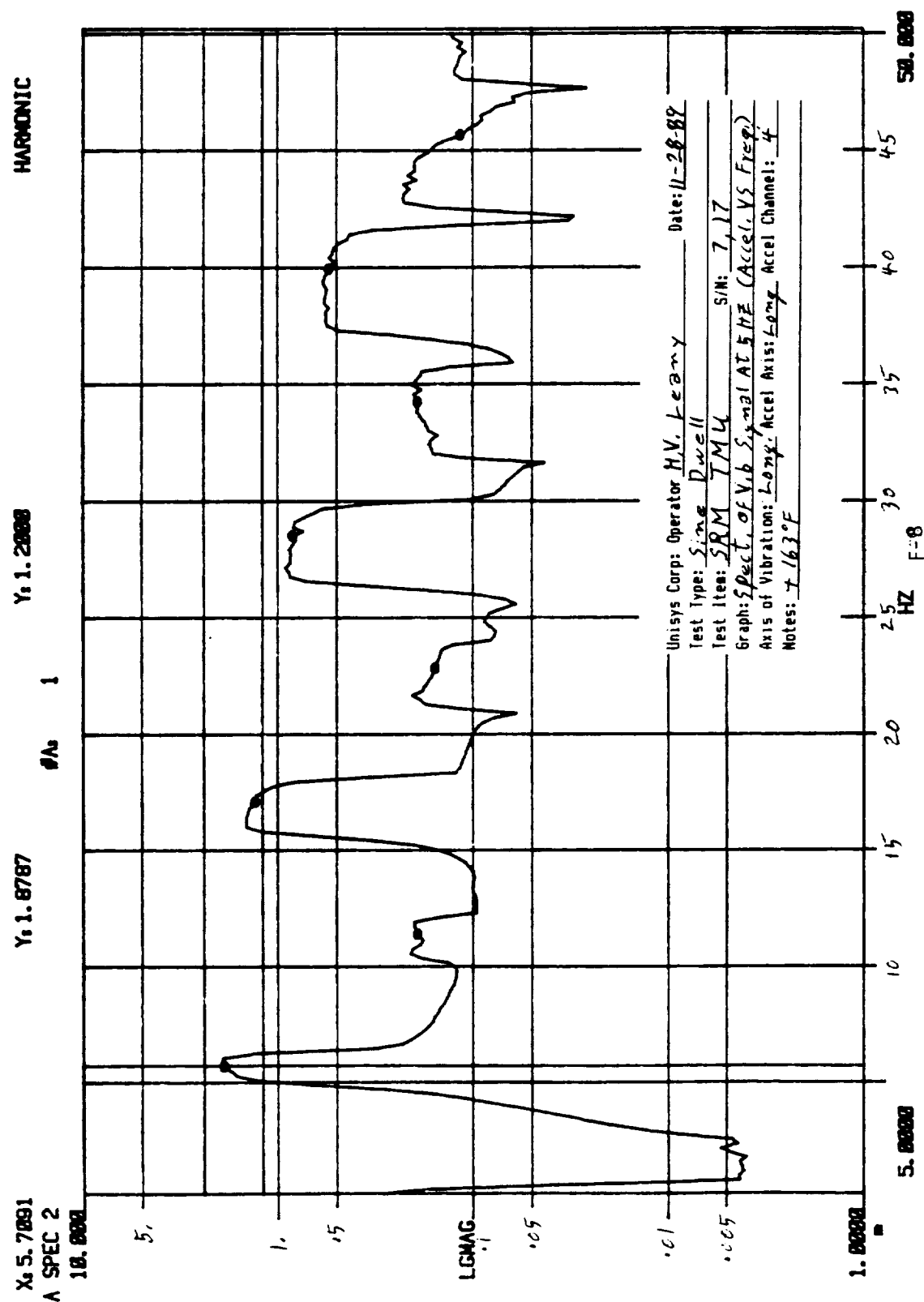
Frequency Hz
Sine Sweep Response F-5



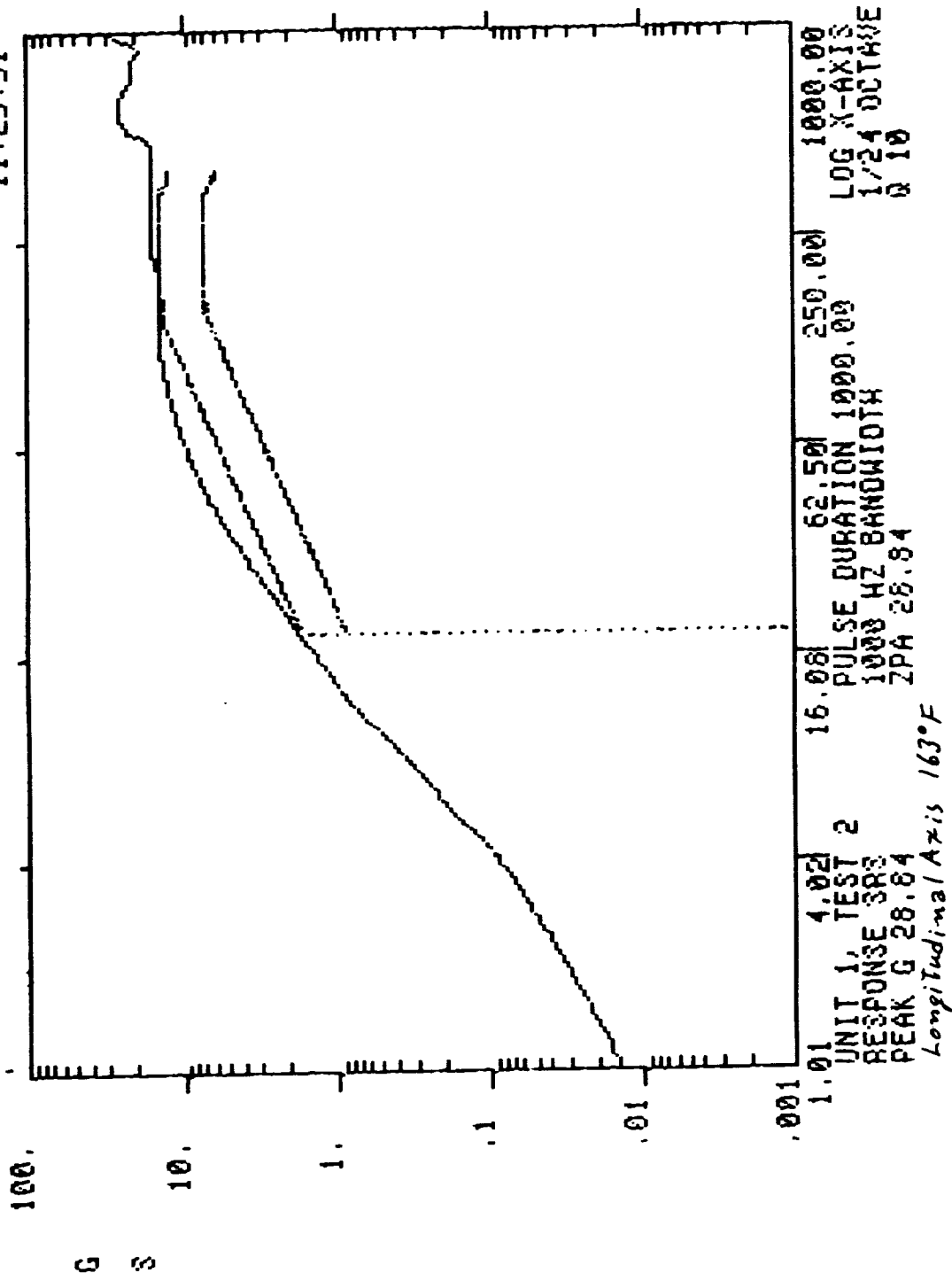
Unisys Corp: Operator H.V. Leary Date: 11-28-89
 Test type: Sine Dwell
 Test Item: SRM TMU S/N: 7, 17
 Graph: Accel. VS Freq.
 Axis of Vibration: Long. Accel Axis: Long Accel Channel: #
 Notes: 163°F

Frequency
 Hz
 Sine sweep F-6
 Reprise





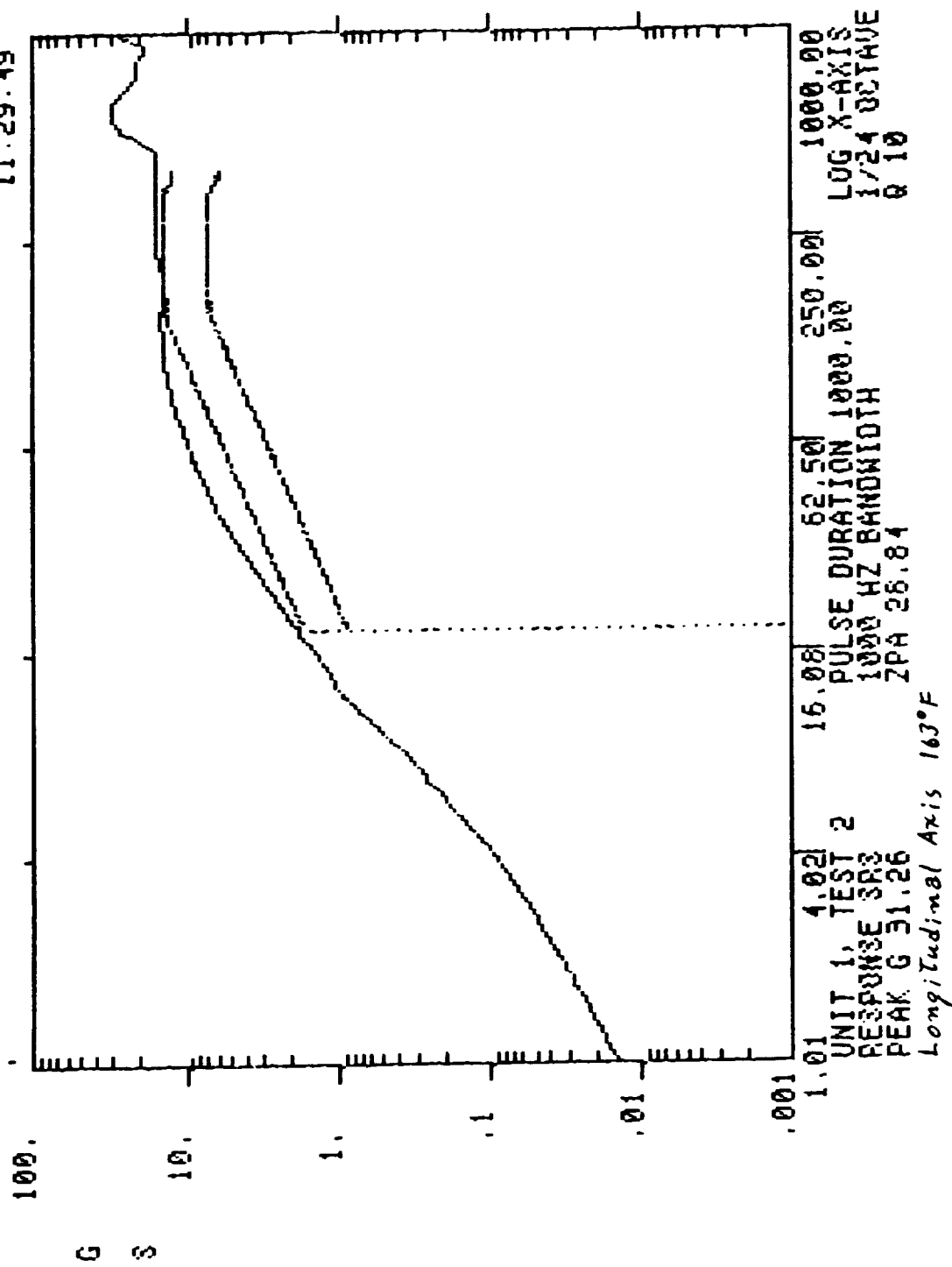
THIOL SRM THU QUALIFICATION COMPOSITE MAXI MAX 28-NOV-89 11:25:31



Shock #1

F-9

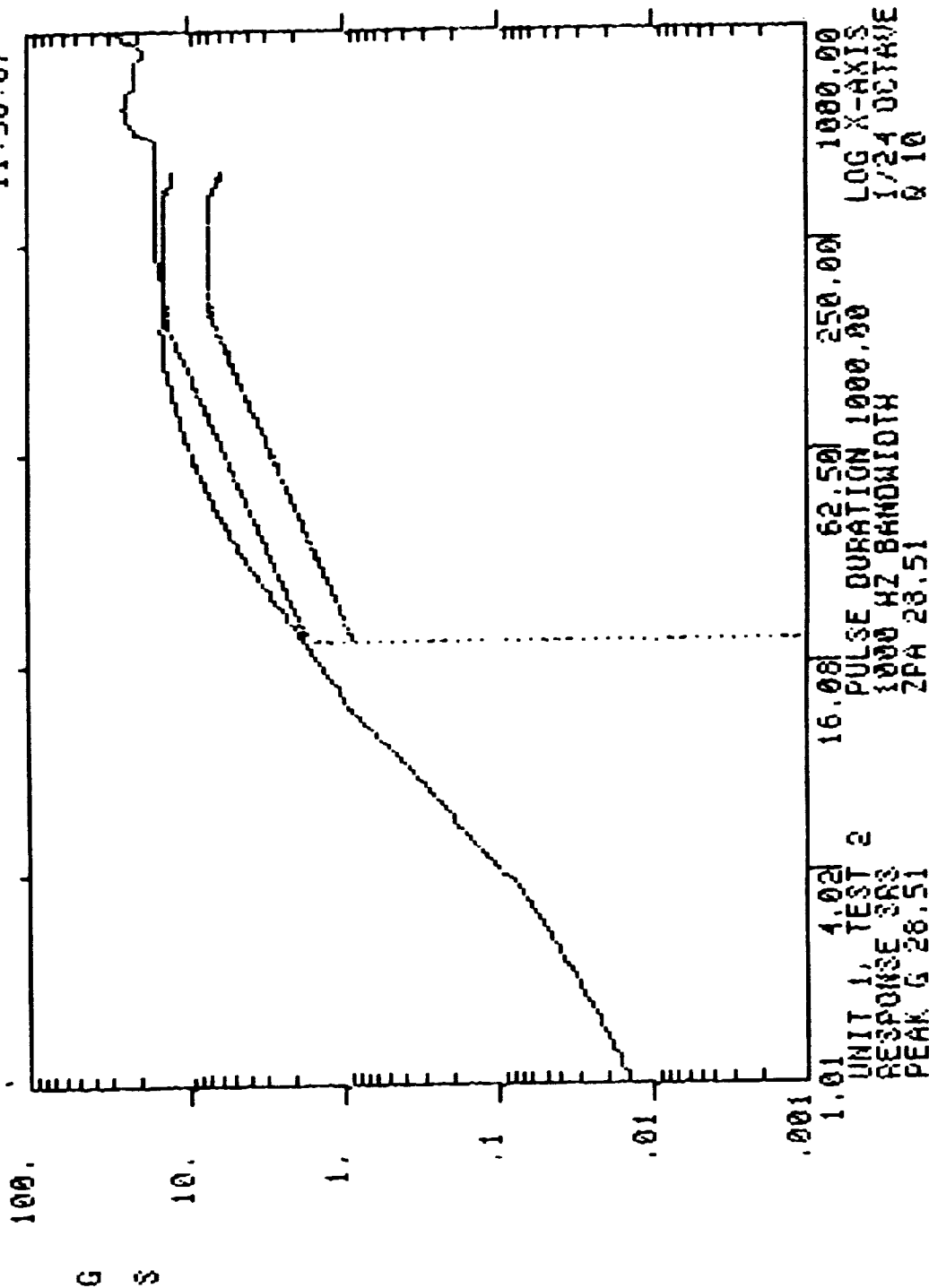
THICKOL SRM TMJ QUALIFICATION COMPOSITE MAXI MAX 28-NOV-89 11:29:49



Shock # 2

F-10

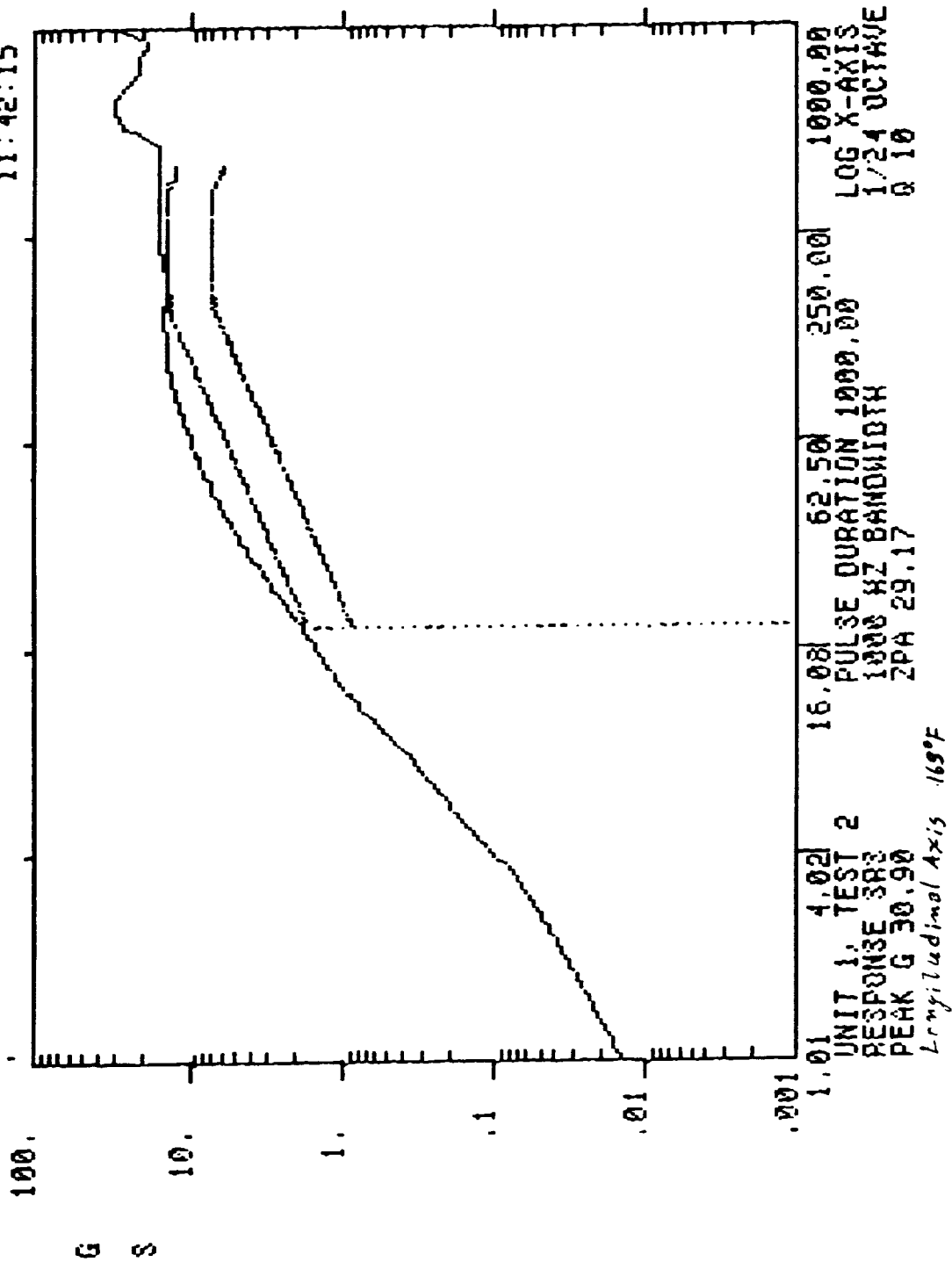
THIOL SRM TMU QUALIFICATION COMPOSITE MAXI MAX 28-NOV-39 11:38:07



Longitudinal Axis 163°F

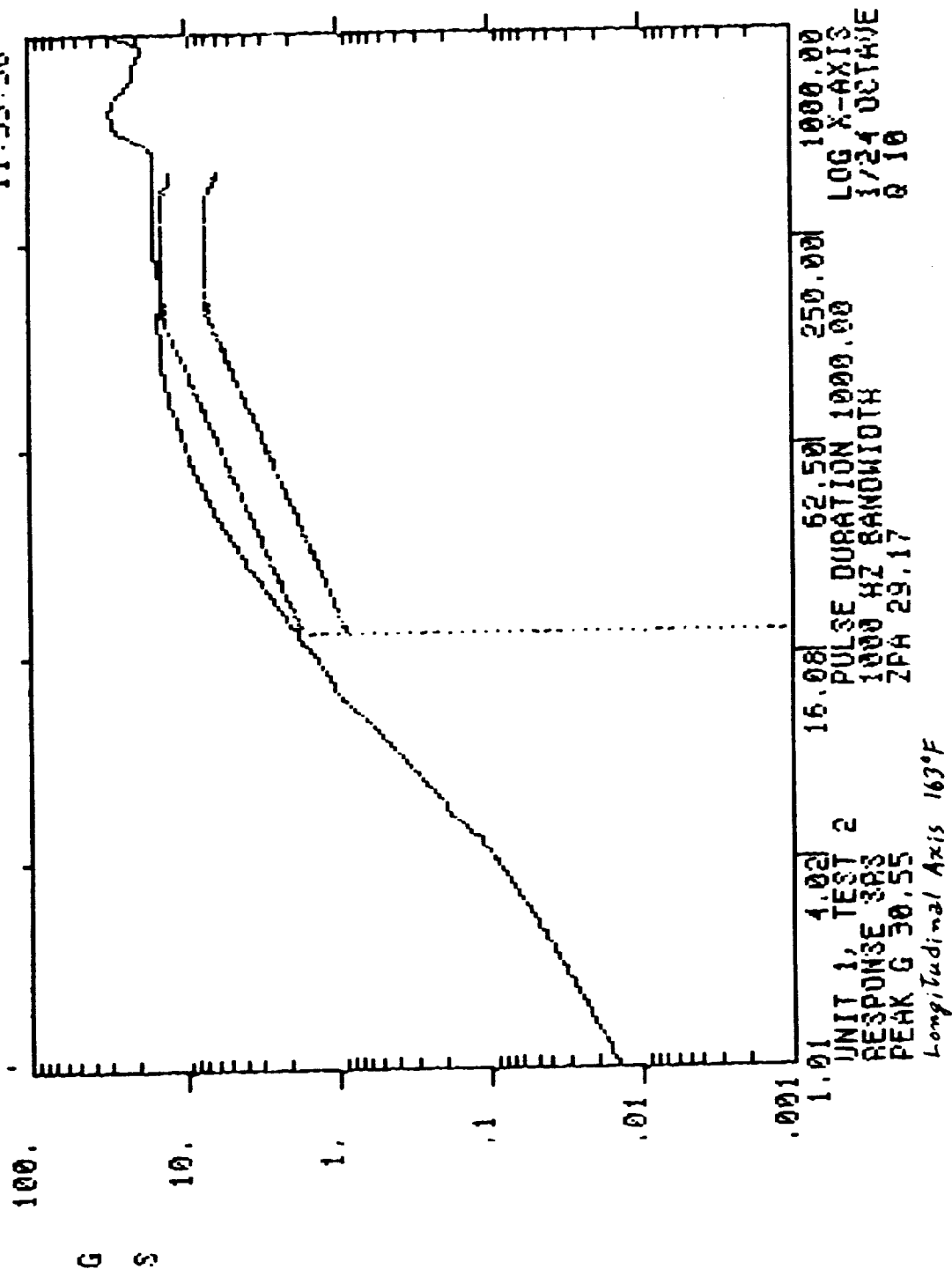
Shock #3

THICKOL SRM TMJ QUALIFICATION COMPOSITE MAXI MAX 28-NOV-89 11:42:15



Shock #4 F-13

THICKOL 3RM TMU QUALIFICATION COMPOSITE MAXI MAX 28-NOV-89 11:33:58



Shock #5 F-11

APPENDIX C

QSI Corporation Memo, QDLM-2 Failure Analysis
(Wyle Laboratories qualification testing), dated 19 Jun 1989



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June 19, 1989

Mr. Milas Brown MS-FO3D
Morton Thiokol, Inc.
Space Operations
P.O. Box 707
Brigham City, UT 84302-0707

Re: QDLM-2 Failure Analysis (Wyle Lab qualification testing)

Dear Miles:

The problems with the two QDLM units at Wyle Laboratories can be broken down into two different types of failures. The first, and far worse type of failure, was the shutdown of the QDLM at approximately 160°F. The second type of failure was the occurrence of truncated events in the recorded data. I will discuss this failure first.

Both boxes under test at Wyle showed occasional truncation errors. This failure was caused by a software error and means that parts of the data recorded during an acceleration event were lost or corrupted. The problem is not new, but up until a few weeks ago, QSI was unable to reproduce the failure in the laboratory making a rapid solution problematic. Although the error is software induced, it is possible that the vibration or temperature environment during testing exacerbated the existing condition. We now have discovered ways of forcing the failure and are converging on a solution to this failure mode.

The truncation error phenomenon, while chronic and undesirable, DOES NOT impugn the reliability of any data not indicated as 'truncated' by the DDR software. In other words, if the DDR software does not notify the user that an event is truncated, then the data in that event is reliable. The result of this malfunction is isolated to causing events marked as 'truncated'. Truncated events usually represent a very small part of the total data gathered in a run, so this type of error will not affect the reliability of the majority of data gathered by the QDLM-2. This problem should be corrected within the next two weeks. I will keep you informed of our progress in this area.

Premature shutdown of one of the QDLM units was a far worse failure in that it terminates the ability of the QDLM to gather any data at all. This failure, while serious, was traced to a simple cause. One of the logic ICs on the CPU board had a temperature sensitive failure mode which allowed it to operate properly below about 160°F, however, it would fail at higher temperatures. The IC was replaced and the board now functions correctly up to 185°F. I have tested both the QDLM units, which

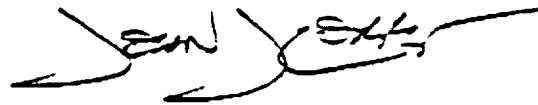
were sent to Wyle, at temperatures up to 135°F. Both units performed properly.

We do not expect this type of problem to occur in the future because all the circuit boards in the QDLM units are burned in at 135°F and are tested to prevent marginal chips from making it to the field. On very rare occasions though, an IC may make it through the battery of tests only to fail in the field. While there is really no way to absolutely guarantee that no ICs will fail in the field, the historical reliability of ICs, after burn in, is very good. We do not expect this failure mode to become an ongoing concern.

I hope this gives you what you need. If you have any questions, please call me.

Sincerely,

QSI CORPORATION

A handwritten signature in black ink, appearing to read "John J. Coffey", with a long horizontal flourish extending to the right.

John J. Coffey
Project Engineer

APPENDIX D

QSI Corporation Report, Failure Analysis of TMUs
No. 006 and 0013, dated 4 Oct 1989



October 4, 1989

Mr. Miles Brown
Thiokol Corporation
Space Operations
MS T44
PO Box 707
Brigham City, UT 84302

Dear Miles:

Enclosed with this letter is a Failure Analysis report prepared by John Coffey, concerning TMU units #0006 and #0013.

As the report indicates, TMU #0006 contained a metal flake which shorted channel 10, but the unit was otherwise functional. This short must have occurred after the unit shipped from QSI, since it passed its acceptance tests. TMU #0013 operated as required, and all data errors can be explained by improper application and installation.

We have spent approximately 750 man-hours this year, without any compensation, trying to find "failures" in these TMUs. We have located and fixed a couple of software problems (related to the truncated events), but to the best of our knowledge the most recent software we have been installing (Version 1.4) has no bugs or problems whatsoever.

For future reference, we will continue to be willing to analyze any suspicious data you retrieve from the TMU units, as follows:

- ▶ We must receive the TMUs and the unerased data modules. Supplying us with paper plots is not adequate for analysis.
- ▶ The actual cables and sensors used are not required, but will greatly simplify any failure analysis. Without these cables and sensors, we can never be sure we have truly identified the cause(s) of any problems.
- ▶ We must have a contract for the man-hours and materials used during the analysis.

If, during any data analysis, we find that a failure is due to original design problems, we will not charge for the analysis, and we will correct the problem in all units, without charge.

If we find a failed component in a TMU, we will request a contract for repair. There are two reasons for this: first, the warranty on these units has long since expired; second, we know

of several instances where some units were exposed to environmental conditions well beyond those specified in the original contract.

If, as has been the case recently, the failures are due to installation or application, we will charge for the time spent doing the analysis.

We have offered to accept a contract for installation and checkout of the TMU units. We still believe that this would be the best route to achieving the performance of which these units are capable.

I have enclosed a disk with the latest DDR data recovery and reduction software. There are two differences between this Version 3.0 software and earlier versions (neither due to software bugs): first, this version clearly displays its version number on all initial menu screens, in all reports, and in all data files; second, the history file format has been improved to show both the maximum levels seen on any trigger channel and the trigger levels seen. Please make sure that your programmers get this new software for all future use, and that all older versions are deleted.

Finally, attached is a summary of where the twenty TMU units are in terms of software upgrades and baseplates. We are performing a complete calibration, as well as your acceptance test and our own (very rigorous) acceptance test at the time of the software upgrades.

Feel free to call me if you have any questions on any of this.

Sincerely,

QSI CORPORATION



James K. Elwell
President

JKE/mw
Enclosure

QDLM-2 (TMU) UPGRADE SUMMARY

October 4, 1989

<u>Serial Number</u>	<u>Software Ver 1.4?</u>	<u>Baseplate Installed?</u>
0001	no	no
0002	no	no
0003	no	no
0004	yes	no
0005	yes	no
0006	no	no
0007	yes	yes
0008	yes	no
0009	yes	yes
0010	no	no
0011	no	no
0012	no	no
0013	yes	no
0014	yes	no
0015	yes	no
0016	no	no
0017	yes	yes
0018	yes	no
0019	no	no
0020	no	no

**FAILURE ANALYSIS
OF TMUs #0006 AND #0013**

To:

**Thiokol Corporation
Brigham City, UT 84302**

From:

**QSI CORPORATION
1740 Research Park Way
Logan, UT 84321
Telephone: 801-753-3657
FAX: 801-753-3822**

October 4, 1989

FOREWORD

This report analyzes the apparent failure of TMUs #0006 and #0013 to gather reliable data during the shipment of eighth flight motors to KSC.

After examining both TMUs and the data acquired by TMU #0013, we feel that the problems seen on this run do not indicate a general failure of the TMU design. The problems encountered are primarily due to improper installation and data reduction errors.

A small metal flake was found in TMU #0006 which caused the malfunction of channel 10 on that unit. At the time of the SRM shipment, TMU #0006 had not been upgraded with the current revision of internal software. No other problems were found with unit #0006.

The unexpected truncated events in data gathered by TMU #0013 were caused by the use of obsolete DDR software in the data reduction stage. This problem was eliminated in later software releases (Version 2.3 or later), but an earlier version was used here.

Two other problems were found in the data acquired by TMU #0013: 1) unusual waveforms on channel 4; 2) unusual waveforms seen on channels 1, 2 and 3. The nature of the recorded data indicates that these problems are due to installation problems and/or bad or loose cables.

There is some question as to whether the accelerometers accompanying TMU #0013 were the ones actually used on the eighth flight shipment. Without the actual equipment used during a run, a thorough analysis of any apparently erroneous data is impossible.

1. Problems with TMU #0006.

TMU #0006 was found to contain a small metal flake in the vicinity of the channel 10 analog electronics. This metal flake shorted analog electronics within TMU #0006, causing channel 10 to become inoperative during the run.

The data recorded by TMU #0006 was not provided to us. The TMU contained old versions of internal software, so random truncated errors may occur in the data recorded by this unit.

The origin of the metallic flake is unknown but it could reasonably be expected to arise either within the SRM shipping environment or during assembly of the TMUs. TMU #0006 was thoroughly tested at the factory prior to its delivery to Thiokol, and was found to be fully operational.

2. Problems with TMU #0013.

2.1. Truncated Events.

The truncated events which occurred near event 144 in the recorded data are fictitious and do not exist in the actual data. They are the result of using obsolete (Version 2.2) DDR software to read the modules for this run. The use of current DDR software eliminates this problem.

The short truncations (less than 128 bytes) at the end of data from each set of modules are expected, and are the result of normal operation of the TMUs.

2.2. Unusual Waveforms - Channel 1, 2 and 3.

The waveforms seen on channels 1, 2 and 3, while unusual, are all quite similar in appearance and form, and correlate in time. This suggests a common cause in their generation. We do not believe these waveforms represent real accelerations experienced by the segment during shipment.

[During simulation trials in the lab, we found we could generate similar waveforms (in three simultaneous channels, correlating in time, appearance and form), simply by loosening the bolts which hold the tri-axial mounting block to its support structure, then subjecting the support structure to low-level shocks.

Since no electronic failures could be found with the TMU, and since channels 1, 2 and 3 are connected to one tri-axial block during shipment, and since the waveforms are easily simulated as described, we can only conclude that the mounting block for these three channels was loose during shipment.

[What about 5 shipments?] 2

2.3. Unusual Waveforms - Channel 4.

Channel 4 recorded numerous suspect waveforms, and was the cause of the large number of triggered events seen during the trip. Analysis of the data shows these items:

- ▶ Numerous events with waveforms typical of a discontinuity, i.e., large instantaneous voltage swings followed by a 2- to 4-second discharge curve. This indicates loose connector(s) or broken wires or both.
- ▶ Numerous events (sometimes coincident with those mentioned above) which show short, quick pulses, sometimes with DC offset levels. These are typical of a loose mounting, and are easily simulated in the lab by very light tapping on an accelerometer.

Because of the nature of the waveforms, and because they often were coincidental with waveforms on channels 1, 2 and 3, and because channel 5, which used the same ADC electronics, operated normally, and because the channel 4 electronics operated perfectly in post-run lab testing, we conclude that the channel 4 accelerometer was mounted loosely and had a loose or broken cable.

There is a possibility of an internal failure in the channel 4 accelerometer causing both types of invalid data, but this cannot be evaluated since we do not know which accelerometer was used for channel 4.

3. Channel 5 Through 10 Data.

After examining the data recorded by channels 5 through 10, we have no reason to suspect these waveforms represent anything other than the actual accelerations experienced by these accelerometers. The characteristics of these waveforms are fully consistent with the type, amplitude, and frequency of accelerations expected on a rail shipment such as this.

4. Trip-History/Recorded-Data Correlation.

The correlation between the trip history, as recorded by Agnello and Stone, and the data recorded by TMU #0013 is quite good. At no time, with one exception (discussed below), did the TMU continuously trigger while the train was stationary on the tracks.

There are a few isolated triggered events during idle periods, all triggered by channel 4. In all cases, the channel 4 waveform is typical of a loose or broken cable losing contact momentarily. There are many possible causes: a person brushing against the cable (if the loose connector is at the TMU, or if the cable is broken near where it can be touched), a slight jolt to cars being coupled or uncoupled, movement of the box while opening or closing the cover, etc.

We would *not* expect to see continuous triggering of events while the train was stationary, and indeed, this was not seen in the data. Continuous triggering of the TMU only occurred while the train was moving or being maneuvered to connect cars. Any vibration occurring during these periods would reasonably be expected to shake loose

connectors or broken cables, thus causing triggered events by continually connecting/disconnecting the accelerometer from the TMU.

The single exception mentioned above occurred on Saturday, September 2, from 20:00:41 to 20:14:54. The trip record indicates the train was stopped from 20:00 to 20:15 on this evening, but the TMU recorded essentially continuous events during this time. We would not expect this to happen if the only problem was a loose or broken cable. However, because of various indications in the data and in the trip record, we believe the train was moving during this period of time.

The first indication of this is the waveforms on channels 5 through 10. These are similar to those recorded during other portions of the trip when the train was moving. At all other times when the log shows the train stopped, there are no signals on channels 5 through 10.

The next indication is the waveforms on channels 1 through 3. Although the actual waveforms are suspect, these three channels never showed any activity except when the train was moving. They showed activity during this period, again indicating that the train was moving.

These facts, along with the general poor quality of the trip record (such as a time of 2453 being followed by a time of 0010) lead us to believe the train was, in fact, moving during this time.

5. Summary.

We believe the data recorded on channels 5 through 10 to be accurate and representative of actual accelerations experienced by the SRM segment during shipment.

The data indicates that the cable for channel 4 was broken or had one or more loose connectors, and was mounted loosely. The alternate cause, an internal failure of the accelerometer, cannot be evaluated.

The waveforms recorded by channels 1 through 3 were probably caused by a loose mounting block on the railcar.

The truncated events shown in the history file given to us were due to an obsolete version of one of the data reduction programs.

TMU #0006 developed an electrical short circuit during the trip. No other problems were found with the TMUs. They both ran flawlessly while undergoing complete and thorough testing in the lab.

APPENDIX E

Shock and Sine Dwell Testing at Unisys (engineering evaluation only)--Results and Calculations

Temperature

-32 F

Shock #1 (Figure 1)

Input peak-to-peak (g)= 1.95

Input Shock Frequency =24 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.968	3.046	2.929	3.007	2.772	3.085	3.007	2.851	2.773	2.772
Percent Error=	52.2%	56.2%	50.2%	54.2%	42.2%	58.2%	54.2%	46.2%	42.2%	42.2%

Average Percent Error= 49.8% (10 channels)

Shock #2 (Figure 2)

Input peak-to-peak (g)= 1.89

Input Shock Frequency =24 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.733	2.811	2.77	2.85	2.616	2.811	2.772	2.694	2.538	2.655
Percent Error=	44.6%	48.7%	46.6%	50.8%	38.4%	48.7%	46.7%	42.5%	34.3%	40.5%

Average Percent Error= 44.2% (10 channels)

70 F

Shock #1 (Figure 3)

Input peak-to-peak (g)= 1.98

Input Shock Frequency =16 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.421	2.342	2.382	2.577	Bad	2.421	2.382	2.382	2.499	2.46
Percent Error=	22.3%	18.3%	20.3%	30.2%	N/A	22.3%	20.3%	20.3%	26.2%	24.2%

Average Percent Error= 22.7% (9 channels)

Shock #2 (Figure 4)

Input peak-to-peak (g)= 1.98

Input Shock Frequency =16 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.343	2.343	2.304	2.499	Bad	2.343	2.304	2.304	2.421	2.382
Percent Error=	18.3%	18.3%	16.4%	26.2%	N/A	18.3%	16.4%	16.4%	22.3%	20.3%

Average Percent Error= 19.2% (9 channels)

130 F

Shock #1 (Figure 5)

Input peak-to-peak (g)= 3.62

Input Shock Frequency =37 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	3.358	3.28	3.241	3.397	3.241	3.358	3.28	3.241	3.358	3.28
Percent Error=	-7.2%	-9.4%	-10.5%	-6.2%	-10.5%	-7.2%	-9.4%	-10.5%	-7.2%	-9.4%

Average Percent Error= -8.7% (10 channels)

Shock #2 (Figure 6)

Input peak-to-peak (g)= 3.62

Input Shock Frequency =38 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	3.28	3.28	3.202	3.28	3.163	3.28	3.241	3.163	3.241	3.202
Percent Error=	-9.4%	-9.4%	-11.5%	-9.4%	-12.6%	-9.4%	-10.5%	-12.6%	-10.5%	-11.5%

Average Percent Error= -10.7% (10 channels)

140 F

Shock #1 (Figure 7)

Input peak-to-peak (g)= 1.62

Input Shock Frequency =15 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	1.796	1.874	1.796	1.835	1.835	1.835	1.757	1.796	1.796	1.796
Percent Error=	10.9%	15.7%	10.9%	13.3%	13.3%	13.3%	8.5%	10.9%	10.9%	10.9%

Average Percent Error= 11.8% (10 channels)

Shock #2 (Figure 8)

Input peak-to-peak (g)= 1.61

Input Shock Frequency =15 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	1.796	1.874	1.796	1.835	1.826	1.835	1.835	1.796	1.835	1.796
Percent Error=	11.6%	16.4%	11.6%	14.0%	13.4%	14.0%	14.0%	11.6%	14.0%	11.6%

Average Percent Error= 13.2% (10 channels)

150 FShock #1 (Figure 9)
-----Input peak-to-peak (g)= 1.02
Input Shock Frequency =23 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	1.092	1.014	1.092	1.132	1.132	1.092	1.053	1.132	1.093	1.093
Percent Error=	7.1%	-0.6%	7.1%	11.0%	11.0%	7.1%	3.2%	11.0%	7.2%	7.2%

Average Percent Error= 7.1% (10 channels)

Shock #2 (Figure 10)
-----Input peak-to-peak (g)= 0.92
Input Shock Frequency =18 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	1.092	1.092	1.053	1.092	1.092	1.053	1.053	1.053	1.053	1.092
Percent Error=	18.7%	18.7%	14.5%	18.7%	18.7%	14.5%	14.5%	14.5%	14.5%	18.7%

Average Percent Error= 16.6% (10 channels)

Temperature

-32 F

Event #1 (Figure 11)

Input peak-to-peak (g)=2.985

Input Shock Frequency =10 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	3.436	3.749	3.475	3.553	3.319	3.631	3.436	3.358	3.866	3.358
Percent Error=	15.1%	25.6%	16.4%	19.0%	11.2%	21.6%	15.1%	12.5%	29.5%	12.5%

Average Percent Error= 17.8% (10 channels)

Event #2 (Figure 11)

Input peak-to-peak (g)=2.985

Input Shock Frequency =10 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	3.514	3.671	3.475	3.513	3.397	3.67	3.553	3.436	5.312	3.397
Percent Error=	17.7%	22.9%	16.4%	17.7%	13.8%	22.9%	19.0%	15.1%	77.9%	13.8%

Average Percent Error= 23.7% (10 channels)

70 F

Event #1 (Figure 12)

Input peak-to-peak (g)=2.930

Input Shock Frequency =10 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.89	2.89	2.89	2.89	Bad	2.812	2.773	2.851	2.773	2.851
Percent Error=	-1.4%	-1.4%	-1.4%	-1.4%	N/A	-4.0%	-5.4%	-2.7%	-5.4%	-2.7%

Average Percent Error= -2.9% (9 channels)

Event #2 (Figure 12)

Input peak-to-peak (g)=2.930

Input Shock Frequency =10 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.89	2.89	2.851	2.89	Bad	2.812	2.812	2.851	2.773	2.851
Percent Error=	-1.4%	-1.4%	-2.7%	-1.4%	N/A	-4.0%	-4.0%	-2.7%	-5.4%	-2.7%

Average Percent Error= -2.9% (9 channels)

130 F

Event #1 (Figure 13)

Input peak-to-peak (g)= 3

Input Shock Frequency =10 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.812	2.812	2.89	2.968	2.89	2.89	2.812	2.89	2.89	2.89
Percent Error=	-6.3%	-6.3%	-3.7%	-1.1%	-3.7%	-3.7%	-6.3%	-3.7%	-3.7%	-3.7%

Average Percent Error= -4.2% (10 channels)

Event #2 (Figure 13)

Input peak-to-peak (g)= 3

Input Shock Frequency =10 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	N/A									
Percent Error=										

Average Percent Error= 0.0% (10 channels)

140 F

Event #1 (Figure 14)

Input peak-to-peak (g)=2.920

Input Shock Frequency =10 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.734	2.734	2.734	2.734	2.695	2.695	2.695	2.656	2.734	2.656
Percent Error=	-6.4%	-6.4%	-6.4%	-6.4%	-7.7%	-7.7%	-7.7%	-9.1%	-6.4%	-9.1%

Average Percent Error= -7.3% (10 channels)

Event #2 (Figure 14)

Input peak-to-peak (g)=2.920

Input Shock Frequency =10 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.734	2.734	2.695	2.734	2.656	2.695	2.695	2.656	2.734	2.617
Percent Error=	-6.4%	-6.4%	-7.7%	-6.4%	-9.1%	-7.7%	-7.7%	-9.1%	-6.4%	-10.4%

Average Percent Error= -7.7% (10 channels)

150 FEvent #1 (Figure 15)

Input peak-to-peak (g)=3.027

Input Shock Frequency =10 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.656	2.577	2.617	2.734	2.617	2.617	2.538	2.656	2.695	2.656
Percent Error=	-12.3%	-14.9%	-13.6%	-9.7%	-13.6%	-13.6%	-16.2%	-12.3%	-11.0%	-12.3%

Average Percent Error= -12.9% (10 channels)

Event #2 (Figure 15)

Input peak-to-peak (g)=3.027

Input Shock Frequency =10 Hz

	Peak-to-Peak Values (g)									
	1	2	3	4	5	6	7	8	9	10
TMU Data (g)=	2.656	2.656	2.617	2.773	2.656	2.617	2.578	2.617	2.656	2.656
Percent Error=	-12.3%	-12.3%	-13.6%	-8.4%	-12.3%	-13.6%	-14.8%	-13.6%	-12.3%	-12.3%

Average Percent Error= -12.5% (10 channels)

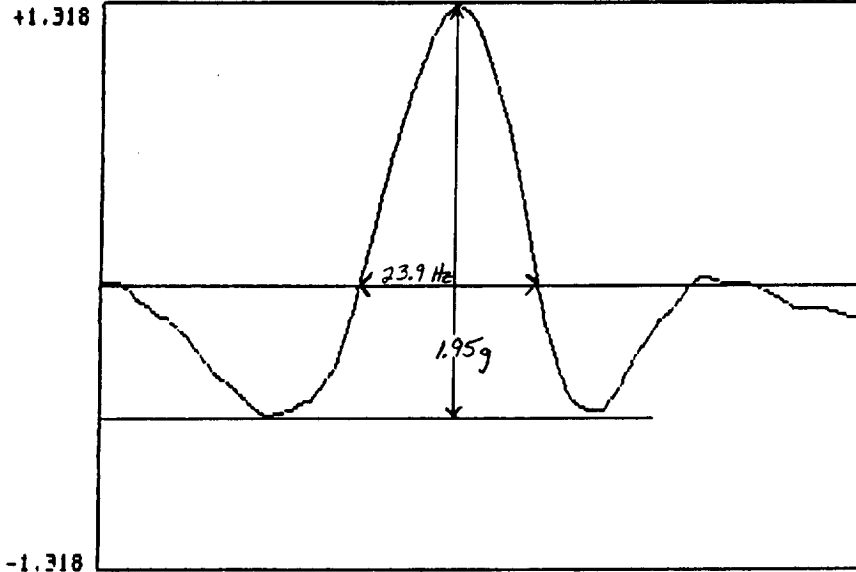
810C PROCEDURE

-32' Shock

1998/12/12
16:19:28.75

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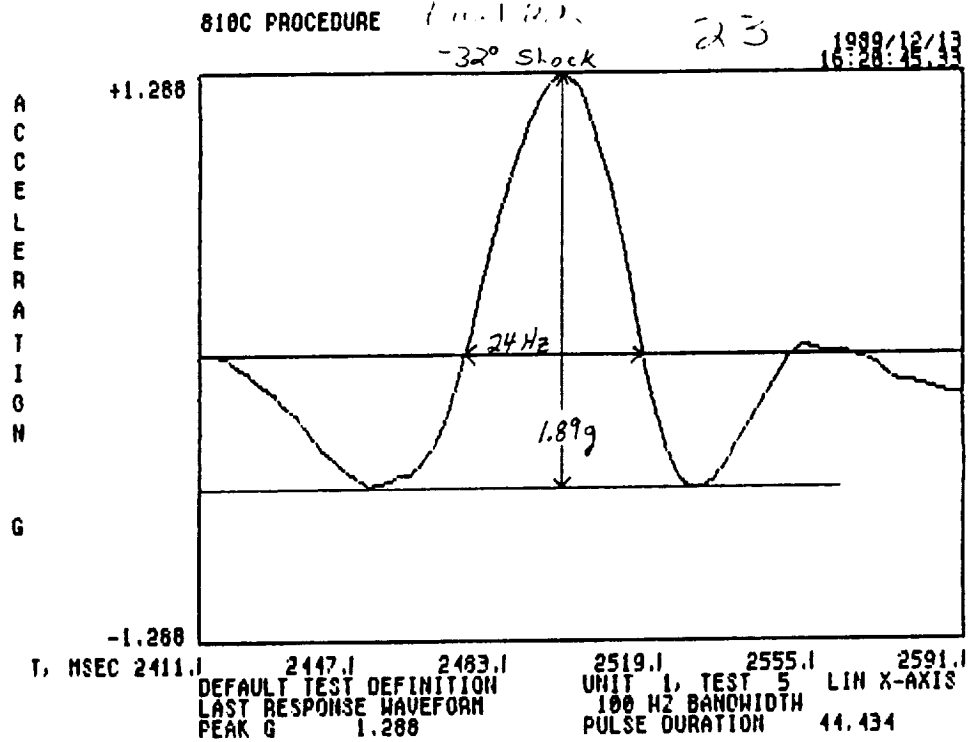


T, MSEC 2411.1 2447.1 2483.1 2519.1 2555.1 2591.1
 DEFAULT TEST DEFINITION UNIT 1, TEST 5 LIN X-AXIS
 LAST RESPONSE WAVEFORM 100 HZ BANDWIDTH
 PEAK G 1.318 PULSE DURATION 44.434

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT	Day/Time	Channel	Minimum	Average	Maximum
21	00 16:22:00	CHANNEL 1	-1.640	-0.031	1.328
		CHANNEL 2	-1.640	-0.034	1.406
		CHANNEL 3	-1.640	-0.018	1.289
		CHANNEL 4	-1.640	-0.011	1.367
		CHANNEL 5	-1.523	-0.017	1.249
		CHANNEL 6	-1.679	0.008	1.406
		CHANNEL 7	-1.640	-0.007	1.367
		CHANNEL 8	-1.562	-0.006	1.289
		CHANNEL 9	-1.406	0.004	1.367
		CHANNEL 10	-1.523	-0.004	1.249

-32' Shock

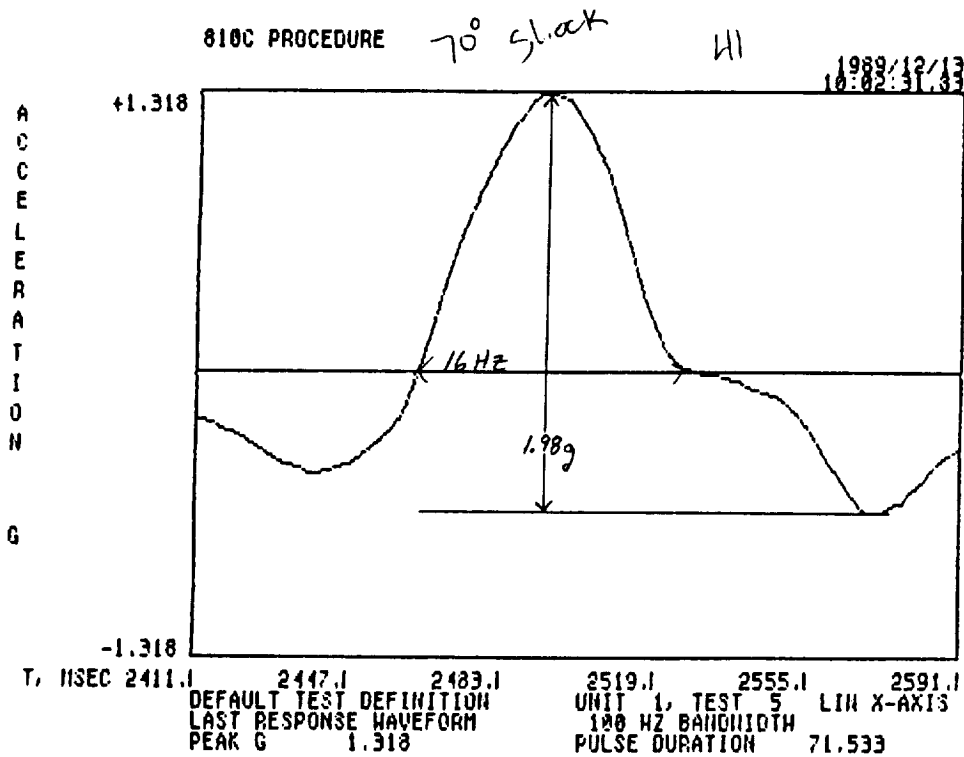


EVENT TIME SUMMARY ACROSS CHANNELS

EVENT	Day/Time	Channel	Minimum	Average	Maximum
22	00 16:23:16	CHANNEL 1	-1.796	-0.018	0.937
		CHANNEL 2	-1.874	-0.028	0.937
		CHANNEL 3	-1.679	0.001	1.093
		CHANNEL 4	-1.757	0.004	1.093
		CHANNEL 5	-1.601	-0.011	1.015
		CHANNEL 6	-1.718	0.018	1.093
		CHANNEL 7	-1.718	-0.003	1.054
		CHANNEL 8	-1.757	-0.007	0.937
		CHANNEL 9	-1.445	0.016	1.093
		CHANNEL 10	-1.718	-0.011	0.937

-32° Shock

ORIGINAL PAGE IS
OF POOR QUALITY



EVENT TIME SUMMARY ACROSS CHANNELS

EVENT	Day/Time	Channel	Minimum	Average	Maximum
41	01 10:02:02	CHANNEL 1	2.421 -1.093	0.007	1.328
		CHANNEL 2	2.342 -1.093	0.009	1.249
		CHANNEL 3	2.382 -1.093	0.011	1.289
		CHANNEL 4	2.577 -1.171	0.006	1.406
		CHANNEL 5	-0.039	-0.014	0.039
		CHANNEL 6	2.421 -1.093	0.007	1.328
		CHANNEL 7	2.382 -1.093	-0.001	1.289
		CHANNEL 8	2.382 -1.093	0.003	1.289
		CHANNEL 9	2.499 -1.132	0.003	1.367
		CHANNEL 10	2.460 -1.132	-0.001	1.328

70° Shock

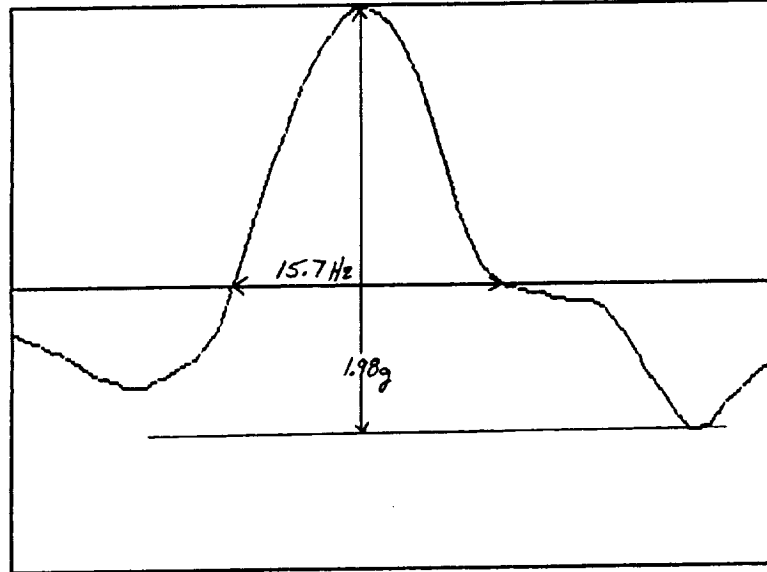
810C PROCEDURE

70° Shock 42

1989/12/13
09:58:58.68A
C
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+1.303



-1.303

T, NSEC 2411.1

2447.1

2483.1

2519.1

2555.1

2591.1

 DEFAULT TEST DEFINITION
 LAST RESPONSE WAVEFORM
 PEAK G 1.303

 UNIT 1, TEST 5
 100 HZ BANDWIDTH
 PULSE DURATION

LIN X-AXIS

63.846

EVENT TIME SUMMARY ACROSS CHANNELS

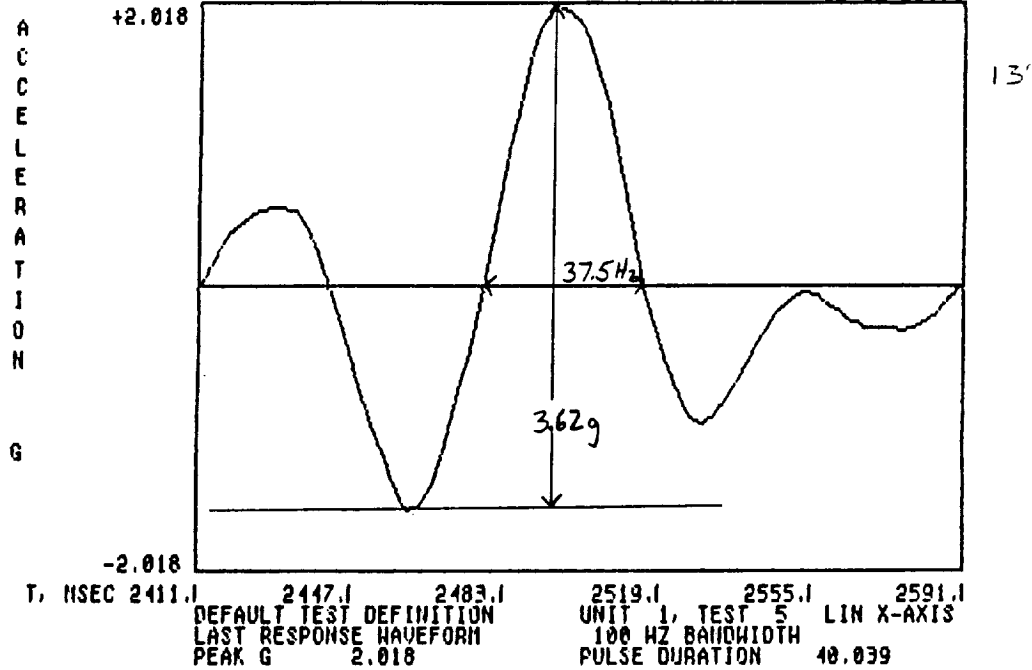
EVENT	Day/Time	Channel	Minimum	Average	Maximum
42	01 10:03:33	CHANNEL 1 2,343	-1.015	0.007	1.328
		CHANNEL 2 2,343	-1.015	0.011	1.328
		CHANNEL 3 2,304	-1.015	0.011	1.289
		CHANNEL 4 2,499	-1.093	0.005	1.406
		CHANNEL 5 2nd	-0.039	-0.014	0.039
		CHANNEL 6 2,343	-1.015	0.009	1.328
		CHANNEL 7 2,304	-1.015	0.000	1.289
		CHANNEL 8 2,304	-1.015	0.002	1.289
		CHANNEL 9 2,421	-1.054	0.002	1.367
		CHANNEL 10 2,382	-1.054	0.000	1.328

70° Shock

810C PROCEDURE

23

12-8-89

1989/12/12
15:02:38.71

130'

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT	Day/Time	Channel	Minimum	Average	Maximum
23	01 15:03:11	CHANNEL 1 3,358	-1.562	-0.032	1.796
		CHANNEL 2 3,280	-1.484	0.026	1.796
		CHANNEL 3 3,241	-1.484	-0.017	1.757
		CHANNEL 4 3,397	-1.562	-0.016	1.835
		CHANNEL 5 3,241	-1.484	-0.017	1.757
		CHANNEL 6 3,358	-1.523	-0.002	1.835
		CHANNEL 7 3,280	-1.484	-0.007	1.796
		CHANNEL 8 3,241	-1.484	-0.012	1.757
		CHANNEL 9 3,358	-1.523	-0.002	1.835
		CHANNEL 10 3,280	-1.484	-0.001	1.796

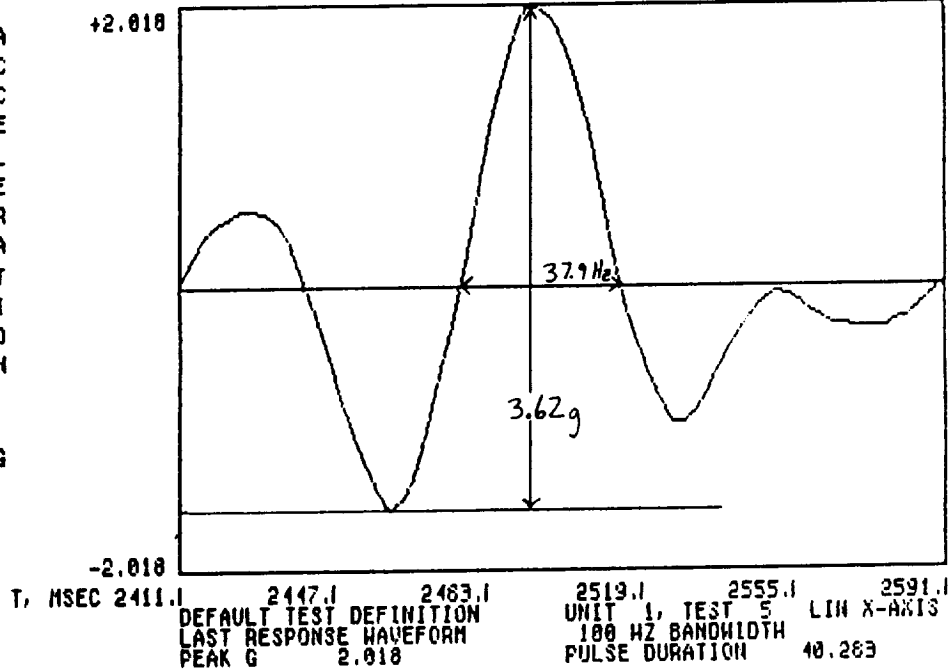
130° Shock.

810C PROCEDURE

261 17-8-87
1989/12/12
15:02:44.06

A
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EVENT TIME SUMMARY ACROSS CHANNELS

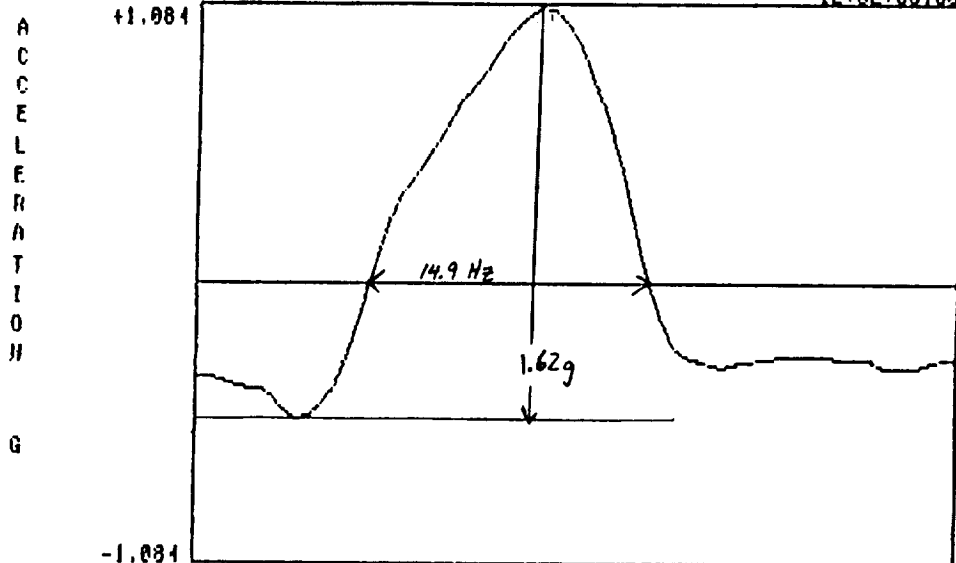
EVENT	Day/Time	Channel	Minimum	Average	Maximum
24	01 15:05:16	CHANNEL 1 3,280	-1.484	-0.031	1.796
		CHANNEL 2 3,280	-1.406	0.025	1.874
		CHANNEL 3 3,202	-1.406	-0.016	1.796
		CHANNEL 4 3,280	-1.445	-0.016	1.835
		CHANNEL 5 3,163	-1.406	-0.016	1.757
		CHANNEL 6 3,280	-1.445	-0.002	1.835
		CHANNEL 7 3,241	-1.445	-0.007	1.796
		CHANNEL 8 3,163	-1.406	-0.010	1.757
		CHANNEL 9 3,241	-1.406	-0.002	1.835
		CHANNEL 10 3,202	-1.406	0.000	1.796

130° S1.00K

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810C PROCEDURE 11/10° Shock

11 1989/12/12
12:02:08.00



T, HSEC 2411.1 2417.1 2483.1 2519.1 2555.1 2591.1
DEFAULT TEST DEFINITION UNIT 1, TEST 5 LIN X-AXIS
LAST RESPONSE WAVEFORM 100 HZ BANDWIDTH
PEAK G 1.084 PULSE DURATION 70.312

EVENT TIME SUMMARY ACROSS CHANNELS

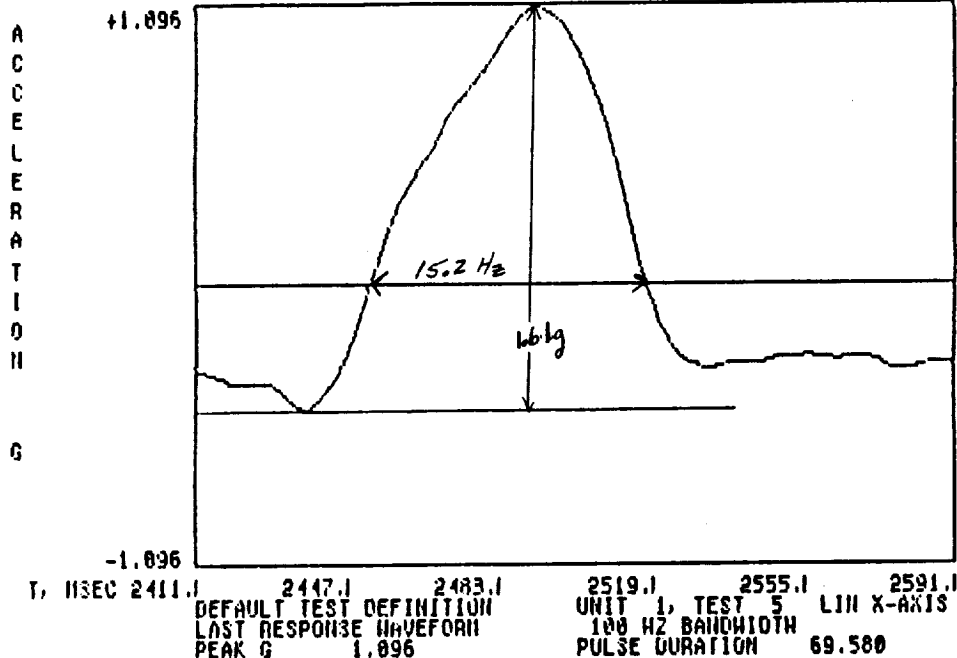
EVENT	Day/Time	Channel	Minimum	Average	Maximum	
23	01 11:51:21	CHANNEL 1	1.80 -0.781	-0.038	1.015 10.0%	1.796
		CHANNEL 2	1.87 -0.703	0.037	1.171 10.0%	1.874
		CHANNEL 3	1.80 -0.703	-0.018	1.093 10.0%	1.796
		CHANNEL 4	1.82 -0.742	-0.017	1.093 10.0%	1.835
		CHANNEL 5	1.35 -0.781	-0.017	1.054 10.0%	1.835
		CHANNEL 6	1.82 -0.742	-0.007	1.093 10.0%	1.835
		CHANNEL 7	1.76 -0.703	-0.009	1.054 10.0%	1.757
		CHANNEL 8	1.80 -0.742	-0.013	1.054 10.0%	1.796
		CHANNEL 9	1.80 -0.703	-0.004	1.093 10.0%	1.796
		CHANNEL 10	1.80 -0.703	-0.001	1.093 10.0%	1.796

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OF POOR QUALITY

810C PROCEDURE 11/0° shock

6.10.1.24

1989/12/18



EVENT TIME SUMMARY ACROSS CHANNELS

EVENT	Day/Time	Channel	Minimum	Average	Maximum	
24	01 11:52:54	CHANNEL 1	1.80 -0.781	-0.033	1.015	9.44%
		CHANNEL 2	1.87 -0.781	0.044	1.093	12.8%
		CHANNEL 3	1.40 -0.742	-0.016	1.054	10.0%
		CHANNEL 4	1.43 -0.742	-0.017	1.093	10.9%
		CHANNEL 5	1.72 -0.781	-0.014	1.054	10.9%
		CHANNEL 6	1.43 -0.742	-0.001	1.093	10.9%
		CHANNEL 7	1.43 -0.742	-0.006	1.093	10.9%
		CHANNEL 8	1.6 -0.742	-0.008	1.054	9.44%
		CHANNEL 9	1.83 -0.742	-0.002	1.093	10.9%
		CHANNEL 10	1.8 -0.742	0.002	1.054	9.44%

1.796

1.874

1.796

1.835

1.826

1.835

1.835

1.796

1.835

1.796

810C PROCEDURE

150° Shock

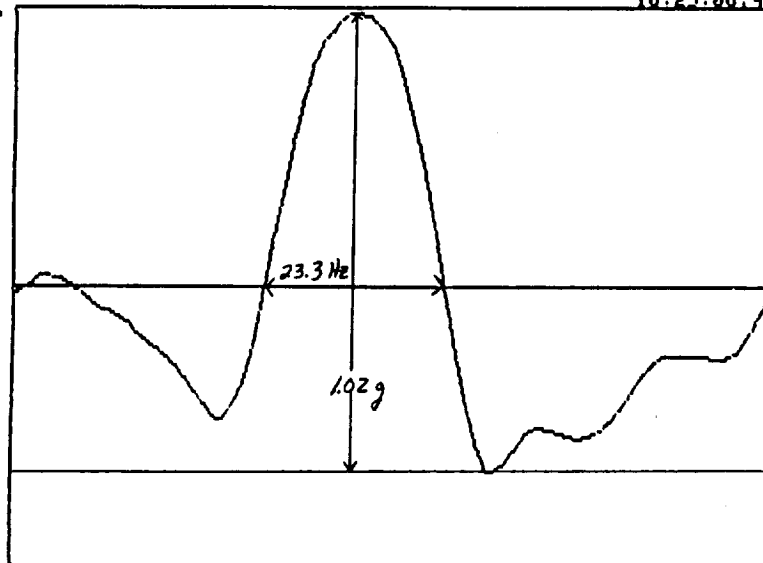
Event 15

2

1989/12/12
16:23:08.35A
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+0.617



-0.617

T, msec 2411.1 2447.1 2483.1 2519.1 2555.1 2591.1
 DEFAULT TEST DEFINITION UNIT 1, TEST 5 LIN X-AXIS
 LAST RESPONSE WAVEFORM 100 HZ BANDWIDTH
 PEAK G 0.617 PULSE DURATION 45.166

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT	Day/Time	Channel	Minimum	Average	Maximum
15	00 16:23:55	CHANNEL 1	1.092 -0.624	0.001	0.468
		CHANNEL 2	1.014 -0.546	0.008	0.468
		CHANNEL 3	1.092 -0.624	0.015	0.468
		CHANNEL 4	1.132 -0.664	0.011	0.468
		CHANNEL 5	1.132 -0.664	-0.001	0.468
		CHANNEL 6	1.092 -0.624	0.006	0.468
		CHANNEL 7	1.053 -0.624	0.002	0.429
		CHANNEL 8	1.132 -0.664	-0.001	0.468
		CHANNEL 9	1.093 -0.664	0.002	0.429
		CHANNEL 10	1.093 -0.664	-0.009	0.429

150° Shock

810C PROCEDURE

150° Shock

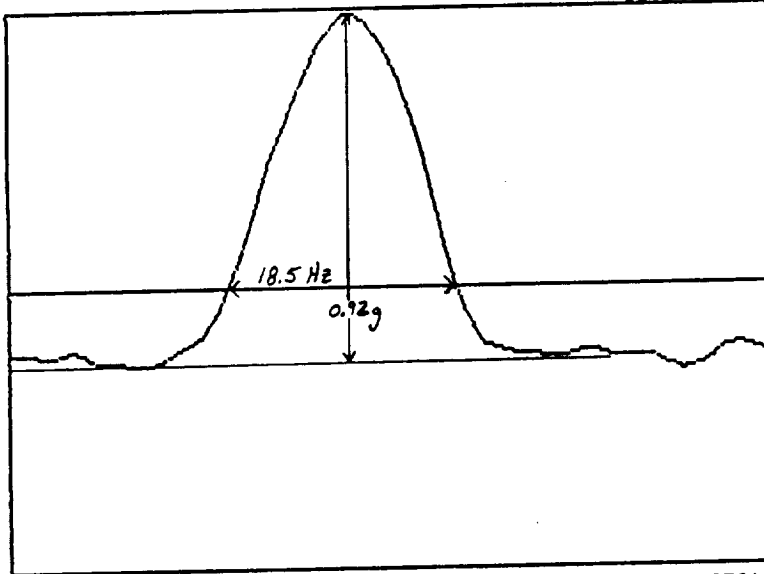
Event 16

3

1989/12/12
16:24:46.65A
C
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G

+0.724



-0.724

T, HSEC 2411.1

 2447.1 2483.1
 DEFAULT TEST DEFINITION
 LAST RESPONSE WAVEFORM
 PEAK G 0.724

 2519.1 2555.1 2591.1
 UNIT 1, TEST 5 LIN X-AXIS
 100 HZ BANDWIDTH
 PULSE DURATION 57.373

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT	Day/Time	Channel	Minimum	Average	Maximum
16	00 16:25:17	CHANNEL 1 1,092	-0.468	0.011	0.624
		CHANNEL 2 1,092	-0.468	0.024	0.624
		CHANNEL 3 1,053	-0.429	0.024	0.624
		CHANNEL 4 1,092	-0.507	0.015	0.585
		CHANNEL 5 1,092	-0.468	0.007	0.624
		CHANNEL 6 1,053	-0.429	0.020	0.624
		CHANNEL 7 1,053	-0.468	0.007	0.585
		CHANNEL 8 1,053	-0.468	0.011	0.585
		CHANNEL 9 1,053	-0.468	0.009	0.585
		CHANNEL 10 1,092	-0.468	0.002	0.624

150° Shock

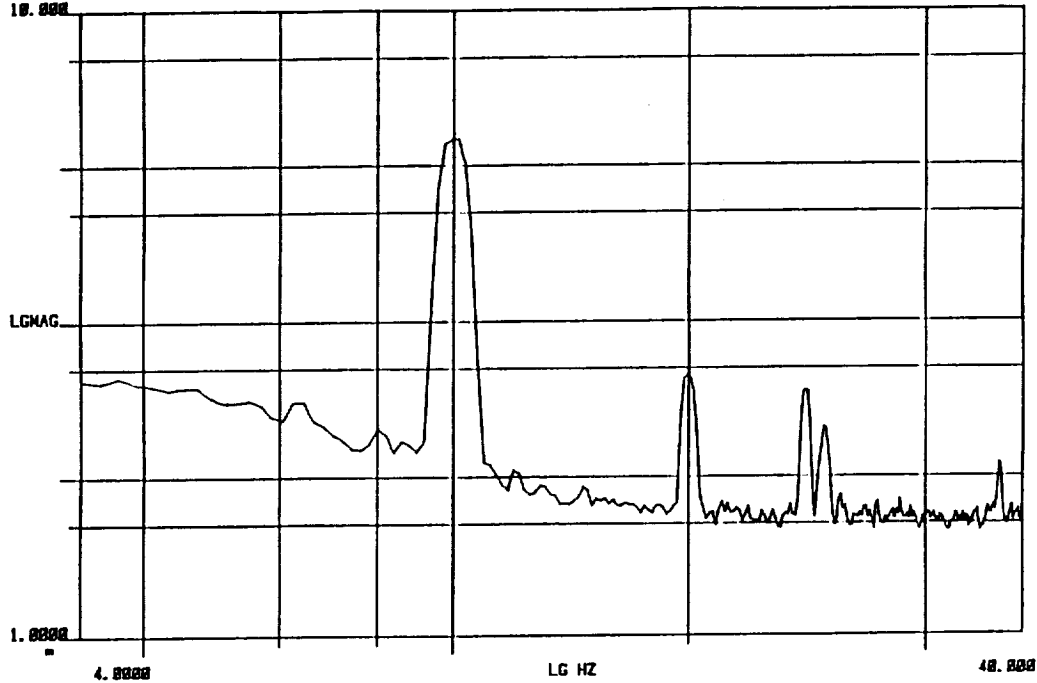
ORIGINAL PAGE IS
OF POOR QUALITY

-32°F

X: 18.885
A SPEC 1
18.888

Y: 1.4929

#A: 1



EVENT TIME SUMMARY ACROSS CHANNELS

EVENT 1	Day/Time	Channel	Minimum	Average	Maximum
7	00 15:28:39	CHANNEL 1	3,436 -1.796	-0.072	1.640
		CHANNEL 2	3,749 -1.953	-0.058	1.796
		CHANNEL 3	3,475 -1.757	-0.028	1.718
		CHANNEL 4	3,553 -1.835	-0.029	1.718
		CHANNEL 5	3,319 -1.718	-0.037	1.601
		CHANNEL 6	3,631 -1.835	-0.006	1.796
		CHANNEL 7	3,436 -1.796	-0.022	1.640
		CHANNEL 8	3,358 -1.718	-0.025	1.640
		CHANNEL 9	3,866 -2.031	0.012	1.835
		CHANNEL 10	3,358 -1.718	-0.018	1.640

100
Shelwell

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT 2	Day/Time	Channel	Minimum	Average	Maximum
8	00 15:28:51	CHANNEL 1	3,514 -1.874	-0.053	1.640
		CHANNEL 2	3,671 -1.953	-0.064	1.718
		CHANNEL 3	3,475 -1.796	-0.037	1.679
		CHANNEL 4	3,513 -1.796	-0.038	1.718
		CHANNEL 5	3,397 -1.757	-0.046	1.640
		CHANNEL 6	3,670 -1.874	-0.016	1.796
		CHANNEL 7	3,553 -1.835	-0.035	1.718
		CHANNEL 8	3,436 -1.796	-0.040	1.640
		CHANNEL 9	5,312 -2.070	-0.031	3.242
		CHANNEL 10	3,397 -1.757	-0.028	1.640

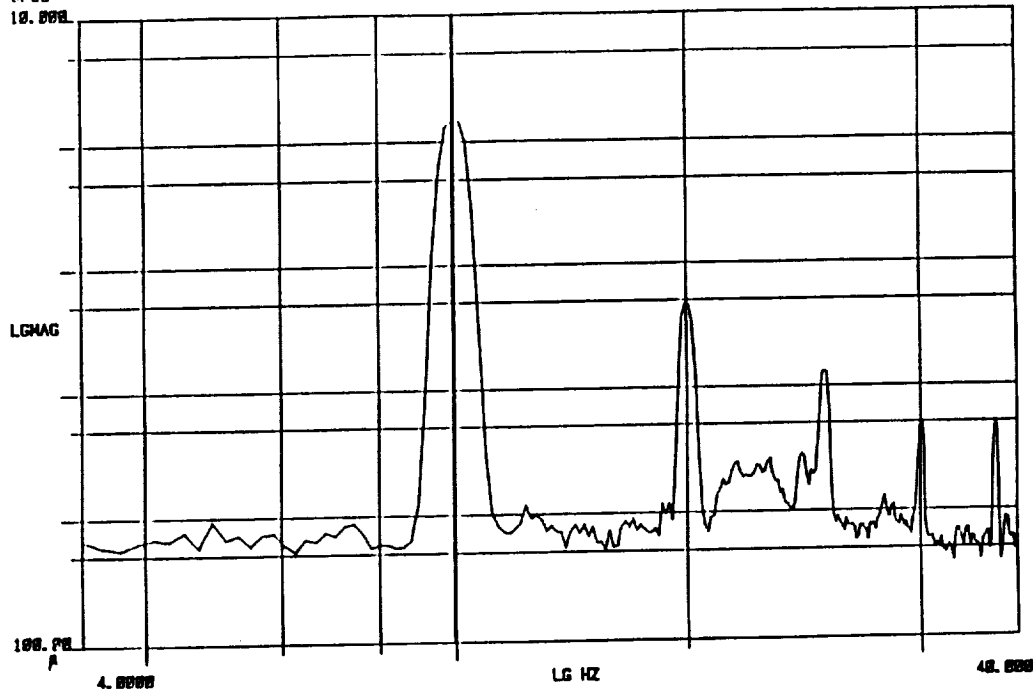
-32 Sine
Dwell

70°F

X: 9.0609
A SFEC
10.000

Y: 1.4853

#A: 1



EVENT TIME SUMMARY ACROSS CHANNELS

EVENT / Day/Time	Channel	Minimum	Average	Maximum
25 01 08:56:59	CHANNEL 1	2.890 -1.406	0.019	1.484
	CHANNEL 2	2.890 -1.406	0.016	1.484
	CHANNEL 3	2.890 -1.406	0.009	1.484
	CHANNEL 4	2.890 -1.406	0.005	1.484
	CHANNEL 5	Bad -0.039	-0.013	0.039
	CHANNEL 6	2.812 -1.367	0.010	1.445
	CHANNEL 7	2.773 -1.367	-0.001	1.406
	CHANNEL 8	2.851 -1.406	0.000	1.445
	CHANNEL 9	2.773 -1.367	0.001	1.406
	CHANNEL 10	2.851 -1.406	-0.001	1.445

70° sine

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT 2 Day/Time	Channel	Minimum	Average	Maximum
26 01 08:57:10	CHANNEL 1	2.890 -1.406	0.024	1.484
	CHANNEL 2	2.890 -1.406	0.017	1.484
	CHANNEL 3	2.851 -1.406	0.008	1.445
	CHANNEL 4	2.890 -1.406	0.005	1.484
	CHANNEL 5	Bad -0.039	-0.012	0.000
	CHANNEL 6	2.812 -1.367	0.011	1.445
	CHANNEL 7	2.812 -1.406	0.000	1.406
	CHANNEL 8	2.851 -1.406	0.000	1.445
	CHANNEL 9	2.773 -1.367	0.001	1.406
	CHANNEL 10	2.851 -1.406	0.002	1.445

70° sine

130°F
Sine Dwell

Input 1.5g 10 Hz

130 ~~220~~ Sine

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT / Day/Time	Channel	Minimum	Average	Maximum
11 01 14:37:07	CHANNEL 1 2,812	-1.328	0.013	1.484
	CHANNEL 2 2,812	-1.328	0.024	1.484
	CHANNEL 3 2,890	-1.367	0.021	1.523
	CHANNEL 4 2,968	-1.406	0.012	1.562
	CHANNEL 5 2,890	-1.367	0.008	1.523
	CHANNEL 6 2,890	-1.367	0.015	1.523
	CHANNEL 7 2,812	-1.328	0.004	1.484
	CHANNEL 8 2,89	-1.367	0.008	1.523
	CHANNEL 9 2,89	-1.367	0.008	1.523
	CHANNEL 10 2,89	-1.367	0.000	1.523

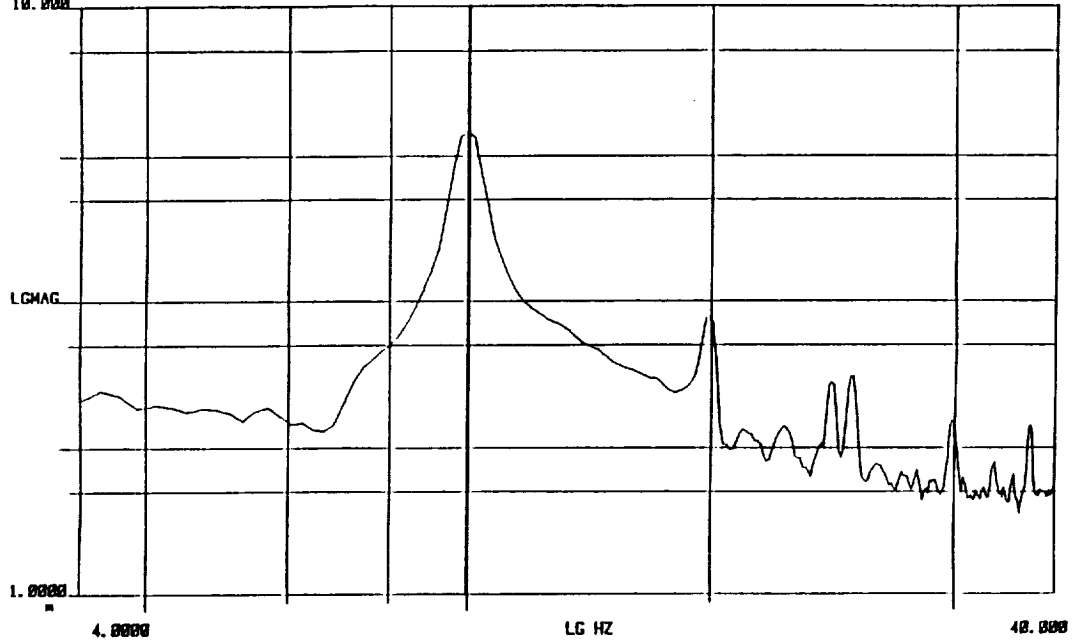
EVENT TIME SUMMARY ACROSS CHANNELS

EVENT 2 Day/Time	Channel	Minimum	Average	Maximum
12 01 14:43:58	CHANNEL 1	-0.468	0.008	0.546
	CHANNEL 2	-0.468	0.022	0.546
	CHANNEL 3	-0.507	0.022	0.546
	CHANNEL 4	-0.507	0.014	0.505
	CHANNEL 5	-0.507	0.010	0.507
	CHANNEL 6	-0.468	0.015	0.546
	CHANNEL 7	-0.468	0.004	0.546
	CHANNEL 8	-0.507	0.008	0.546
	CHANNEL 9	-0.507	0.010	0.546
	CHANNEL 10	-0.507	0.001	0.546

X: 9.9689
A SPEC 2
10.000

Y: 1.4682

#A: 1



EVENT TIME SUMMARY ACROSS CHANNELS

EVENT / Day/Time	Channel	Minimum	Average	Maximum
9 01 10:52:00	CHANNEL 1 2.734	-1.406	-0.033	1.328
	CHANNEL 2 2.734	-1.328	0.038	1.406
	CHANNEL 3 2.734	-1.367	-0.017	1.367
	CHANNEL 4 2.734	-1.367	-0.019	1.367
	CHANNEL 5 2.695	-1.367	-0.017	1.328
	CHANNEL 6 2.695	-1.328	-0.001	1.367
	CHANNEL 7 2.695	-1.328	-0.003	1.367
	CHANNEL 8 2.656	-1.328	-0.008	1.328
	CHANNEL 9 2.734	-1.367	-0.001	1.367
	CHANNEL 10 2.656	-1.289	0.004	1.367

EVENT TIME SUMMARY ACROSS CHANNELS

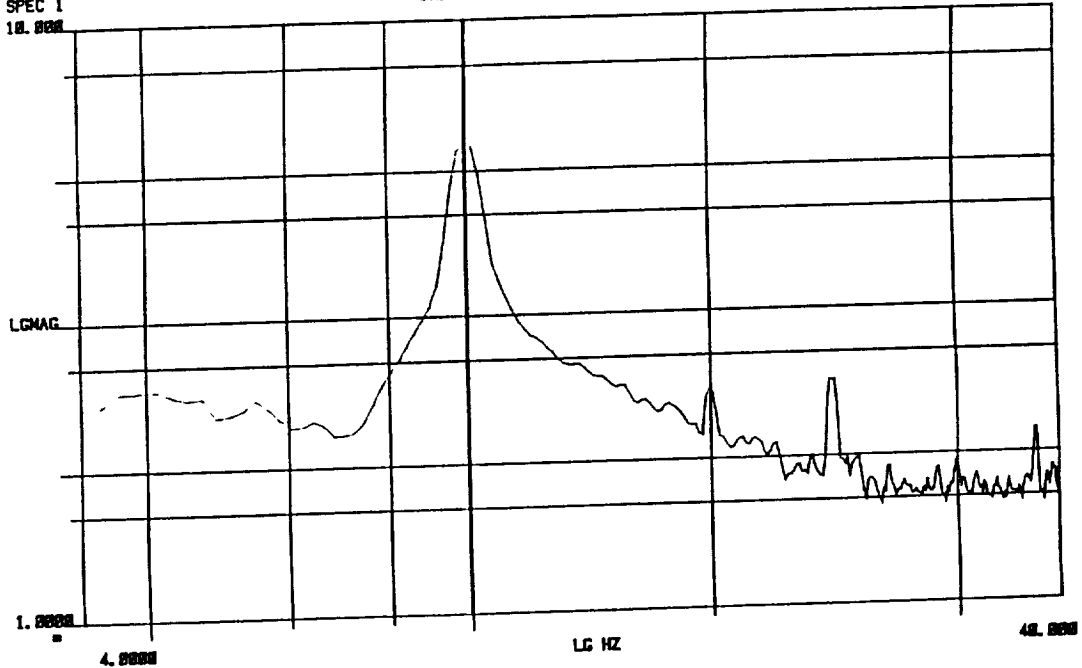
EVENT 2 Day/Time	Channel	Minimum	Average	Maximum
10 01 10:52:12	CHANNEL 1 2.734	-1.406	-0.035	1.328
	CHANNEL 2 2.734	-1.328	0.036	1.406
	CHANNEL 3 2.695	-1.367	-0.019	1.328
	CHANNEL 4 2.734	-1.367	-0.018	1.367
	CHANNEL 5 2.656	-1.328	-0.015	1.328
	CHANNEL 6 2.695	-1.328	-0.002	1.367
	CHANNEL 7 2.695	-1.328	-0.001	1.367
	CHANNEL 8 2.656	-1.328	-0.009	1.328
	CHANNEL 9 2.734	-1.367	0.001	1.367
	CHANNEL 10 2.617	-1.289	0.003	1.328

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X: 9.9009
A SPEC 1
10.000

Y: 1.5137

#A: 1



EVENT TIME SUMMARY ACROSS CHANNELS

EVENT/	Day/Time	Channel	Minimum	Average	Maximum
3	00 16:03:47	CHANNEL 1	2.656 -1.328	0.013	1.328
		CHANNEL 2	2.577 -1.249	0.026	1.328
		CHANNEL 3	2.617 -1.289	0.022	1.328
		CHANNEL 4	2.734 -1.367	0.012	1.367
		CHANNEL 5	2.617 -1.289	0.006	1.328
		CHANNEL 6	2.617 -1.289	0.013	1.328
		CHANNEL 7	2.538 -1.249	0.004	1.289
		CHANNEL 8	2.656 -1.328	0.004	1.328
		CHANNEL 9	2.695 -1.328	0.004	1.367
		CHANNEL 10	2.656 -1.328	-0.004	1.328

150° Sine Wave

EVENT TIME SUMMARY ACROSS CHANNELS

EVENT 2	Day/Time	Channel	Minimum	Average	Maximum
4	00 16:03:58	CHANNEL 1	2.656 -1.328	0.012	1.328
		CHANNEL 2	2.656 -1.328	0.018	1.328
		CHANNEL 3	2.617 -1.289	0.025	1.328
		CHANNEL 4	2.773 -1.367	0.015	1.406
		CHANNEL 5	2.656 -1.328	0.008	1.328
		CHANNEL 6	2.617 -1.289	0.015	1.328
		CHANNEL 7	2.578 -1.289	0.003	1.289
		CHANNEL 8	2.617 -1.289	0.008	1.328
		CHANNEL 9	2.656 -1.328	0.009	1.328
		CHANNEL 10	2.656 -1.328	-0.002	1.328

150° Sine Wave

10.15

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